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Department of
OCEANOGRAPHY AND METEOROLOGY



OCEANOGRAPHY AND METEOROLOGY OF THE GULF OF MEXICO

ANNUAL REPORT

1 May 1962—30 April 1963

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Texas A. & M. Research Foundation
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The Agricultural and Mechanical College of Texas
Department of Oceanography and Meteorology
College Station, Texas

Research conducted through the
Texas A and M Research Foundation

A and M Project 286

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Report Prepared 15 July 1963

by

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INTRODUCTION

The most encouraging developments in this project year have been with regard to the study of the Yucatan Current. Surveys in this region under the direction of Mr. Cochrane have constituted a large part of the field effort for several years. The flow regime is complex and not susceptible to description on the basis of cursory examination. As evidenced in the body of this report, the collection and examination of data from the many cruises is reaching a point where some generalizations can be made concerning the nature, variations, and dynamics of the flow.

Mr. Cochrane led the scientific team on board the Argentine Vessel LASERRE during the first phase of the cooperative investigation of the Equatorial Atlantic. The area assigned to that ship off Northern Brazil turned out to be a most interesting one involving the region where the Equatorial Undercurrent first appears. At the present stage of analysis the data promise to yield information on the origin of this subsurface flow.

The instrumentation of the fixed platforms off Panama City, Florida continued, and at the end of the contract year had progressed to the point that some continuous data could be collected and analyzed by fully automated methods. Prospects are good that the original concept can be shown to be feasible. Much has been learned concerning the limitations of available sensors for fixed station data reception. It seems clear that, after moderate revision of the data handling system, the total system will be sensor limited.

Seismic refraction work was concentrated on the continental shelf south of the Florida Panhandle where a trough-like feature in what has been tentatively construed as the pre-Cretaceous surface suggests an extension of the Gulf Coast Geosyncline.

Studies of the carbonate sediments on Campeche Bank continued and a reconnaissance survey of Mosquito Bank off the coast of Honduras was carried out.

In the chemical oceanography and geochemistry program, an expedition during October was successful in pumping water from as

deep as 3400 meters in quantities sufficient for radioactive dating of organic carbon, analyses for lipid material, rare earth elements, general organic content, and amino acids. Much of the processing was done on board and, in some cases, in a continuous flow technique.

FIELD PROGRAM

The research vessel HIDALGO carried out 14 cruises during the contract year. In January this ship was retired from service in anticipation of its replacement by the ALAMINOS, under conversion in New Orleans and now scheduled for completion in August 1963. Supplementary field work has been carried out with the small vessels DROGUE and ANTILLA out of Panama City and with the VIRAZON, received on loan in December and given minor refit to make some use possible. The HIDALGO cruises are listed below.

Since the HIDALGO was not available to take part in the EQUALANT I survey, a cooperative arrangement with the Argentine Navy was worked out. Mr. Cochrane acted as chief scientist on the COMODORE LASERRE during this survey.

Cruise 62-H-4. 7 May to 28 May 1962, J. D. Cochrane in charge. Investigated Yucatan Current and related currents over Yucatan Shelf. Observed upwelling situation on the north shore of the Yucatan Peninsula.

Cruise 62-H-5. 5 June to 13 June 1962, H. J. McLellan in charge. Student training.

Cruise 62-H-6. 20 June 1962, W. Wilson in charge. Slick survey off Galveston.

Cruise 62-H-7. 21 June to 22 June 1962, P. Dehlinger in charge. Test surface-ship gravity meter at sea.

Cruise 62-H-8. 23 June to 24 June 1962, A. Collier in charge. NSF high school teachers' cruise.

Cruise 62-H-9. 27 June to 12 July 1962, B. W. Logan in charge. Establishment of instrument post, sampling on East Campeche Bank, and geological studies on Campeche Bank.

Cruise 62-H-10. 18 July to 13 August 1962, L. S. Kornicker in charge. Collecting sediment samples, obtaining atmospheric radiation data, obtaining terrestrial gravitation data, measuring evaporation rate of sea water in Galveston, Jamaica, Nicaragua, and Honduras areas.

Cruise 62-H-11. 27 August to 28 August 1962, P. Dehlinger in charge. Gravity meter reliability tests past Pure Oil Platform off Galveston.

Cruise 62-H-12. 2 September to 28 September 1962, J. W. Antoine in charge. Seismic refraction program on the shelf south of the Florida Panhandle.

Cruise 62-H-13. 7 October to 18 October 1962, D. W. Hood in charge. Obtaining large deep water samples in central Gulf of Mexico.

Cruise 62-H-14. 18 October 1962, S. El-Sayed in charge. Biological investigations off Galveston.

Cruise 62-H-15. 23 October to 15 November 1962, J. D. Cochrane in charge. Study of Yucatan Current adjacent to Yucatan Bank and upwelling regions over eastern portion of bank.

Cruise 62-H-16. 19 November to 21 November 1962, B. R. Jones in charge. To test reliability of the LaCoste-Romberg ship surface gravity meter off Galveston.

Cruise 63-H-1. 11 January to 12 January 1963, B. R. Jones in charge. To test reliability of LaCoste-Romberg Meter off Galveston.

STUDIES

Summaries of studies carried out during the year appear below as prepared by the various investigators.

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A. Yucatan Current

John D. Cochrane

During the year, two cruises were made to the Yucatan Current region, one in May and one in October. Data reduction was carried on for these and previous cruises. Some preliminary results of analysis are presented below.

The Yucatan Current is the northerly flow through the Yucatan Strait which extends between roughly 18° and 24°N. Its outstanding feature is its westward intensification, which reaches a maximum in the segment extending from about 30 miles south to 100 miles north of the Strait.

Seasonal Changes

On the basis of the U. S. Navy H. O. Current Atlas of the North Atlantic Ocean (H. O. Misc. 10,688 of 1946), the Yucatan Current at the surface reaches a maximum in June and a minimum in November after a rather sharp drop in September and October, which begins somewhat earlier and is less steep than that found in the Florida Current according to Fuglister (1951). (The speeds near the current core are much higher than those indicated in H. O. Misc. 10,688.)

When the current is strong its core is farthest west, being pressed against the edge of Yucatan Peninsula or Yucatan Shelf. The current core then tends to follow the contours closely, lying near the 100 fm line when strongest.

The BT temperature sections and GEK's of the May 1962 cruise, when flow was not especially strong, give an unusually clear picture of the tendency of the current core to follow an isobath, the 240 fm curve. This was a considerably greater depth than that followed in May 1961, which was close to 100 fm. In extremely strong current conditions, a pressure jump appears to form near the westward jog in the edge of the shelf. Downstream from it the current tends to meander, although a secondary core appears to reform along the eastern edge of the shelf in the north. Divergence above the core reaches a maximum as evidenced by a band of cool water at the surface.

Beyond the north edge of the shelf, the current extends on a more or less straight course to the NNE, sometimes reaching almost to the Mississippi Delta.

When the current is weak, its core is diffuse, lies farther east, and tends to meander, apparently not following the bottom contours. North of the Yucatan Shelf, the current is more frequently found to turn eastward passing around the north side of a small Cuban Eddy centered relatively farther south. There is no evidence of divergence above the core.

The Surface Velocity Field

Profiles of the current taken in April and May are shown in Figure 1A. The component of velocity parallel to the core is plotted against distance measured normal to the core. Three types of data are used, direct measurements of current made by Pillsbury (1890) in 1887, geostrophic velocity computed from Atlantis cruise of May 1933, and GEK measurements taken in May 1961 and 1962. The profiles are remarkably similar. Flanking the core on the left is a zone of extreme cyclonic shear. Immediately to the right of the peak speed is a band of moderate anticyclonic shear 30 to 50 miles wide. This might be called the Yucatan Current proper. To the right (east) of this, the shear suddenly becomes greater and continues normally through the current reversal to the band of southerly currents off Cape San Antonio (Cuba).

The agreement among the different types of information lends weight to the GEK measurements and serves as evidence that the current is approximately geostrophic.

An oddity in observations of the band of largely moderate anticyclonic shear is the sharp minimum in speed occurring between 5 and 15 miles to the right of the core. This appears in the May 1961 section and in six out of eight 1962 GEK sections. It is interesting to note that such a minimum appears in Pillsbury's measurements. Many of the GEK sections across the Florida Straits off Miami given by Murray (1952) show a similar notch. A section across the Gulf Stream proper, given by Worthington (1954), shows this feature in both geostrophic velocities and GEK measurements. On the other hand, the feature is absent when the Yucatan Current is weak.

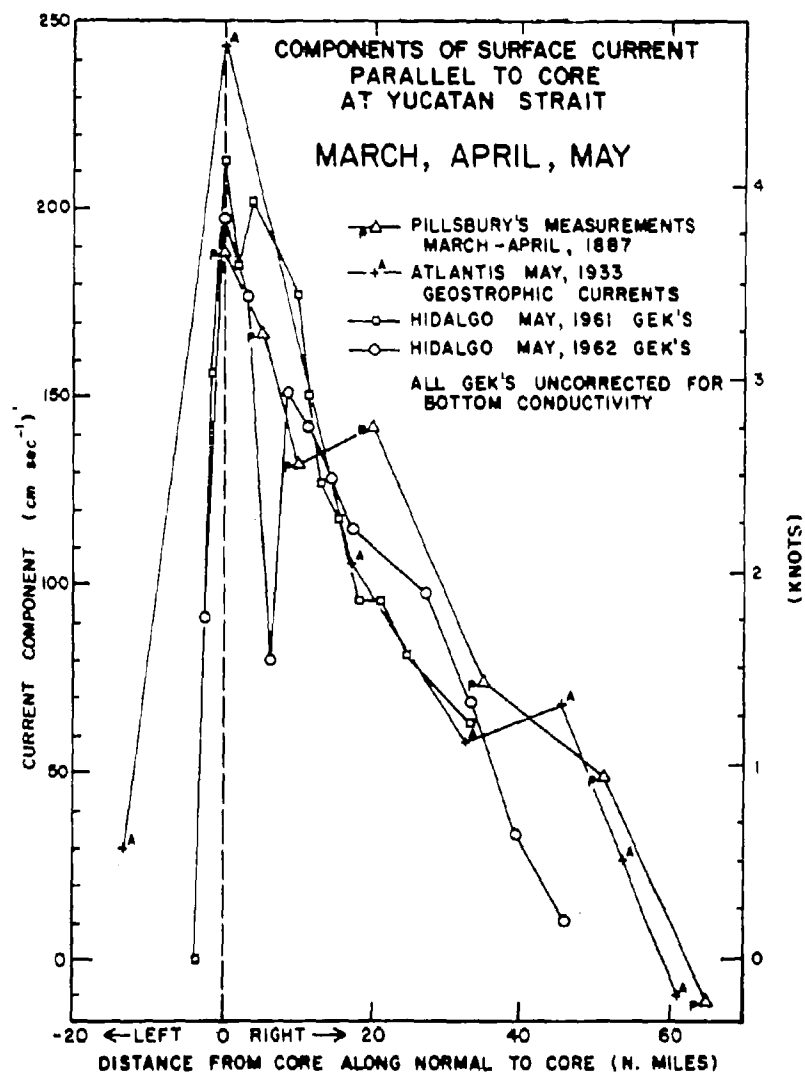


Fig. 1. Surface current profile in April and May at Yucatan Strait.

In May 1962, a series of seven sections across the Yucatan Current were taken between the strait and 110 miles north of it. Figure 2A shows the GEK current profiles across these sections. Somewhat surprisingly, the highest speed was encountered on the northernmost section. The downstream change in the profile is small, consisting largely of erosion of the contrast between the moderate shear in the east and the loss of the sharp, narrow drop in speed to the right of the core. Where the current turned westward at the bend in the bottom contours about 60 mi north of the strait, the cyclonic shear zone left of the core widened considerably. It became narrow and intense again along the shelf edge farther north.

During May 1962, there appeared to be a single continuous current core which could be traced from the Yucatan Strait to the north edge of the Yucatan Shelf, contrasting with the core in May 1961 which appeared to break near the westward jog in the shelf edge, with a weak core appearing farther north along the shelf edge. As in 1961, the isotherms in the core reached their shallowest near the westward jog. However, there was no sharp deepening in the isotherms north of the jog, merely a gradual sinking.

An intriguing aspect of the May current profile in the band of moderate anticyclonic shear at Yucatan Strait is that, except for the notch, the potential vorticity is nearly constant across the current, as Stommel (1958) indicates is true for the Gulf Stream proper. It is possible to compute the speed anywhere in the band by integrating the expression for constant potential vorticity if the speed and lateral shear are known at a point in the band. The degree of agreement between GEK speeds and those computed from constant vorticity is shown in Figure 3A. This agreement seems to point to an origin where potential vorticity is widely uniform, as possibly occurs in the North Equatorial Current region, or where such a modification is brought about by wind or cross-stream mixing, as perhaps in the central Caribbean. Florida Current profiles also at times conform to this pattern. However, the shear at the eastern edge usually seems to be greater. Similar cross-stream profiles are found north of the strait in the Yucatan Current, although the distinction between the current proper and the eddy becomes diffuse.

Conditions in the Yucatan Current during late October and early November can be studied on the basis of cruises in 1959, 1961, and 1962. In 1959 the current was fairly strong, in 1961 quite weak, and in 1962, when the most complete series of current observations

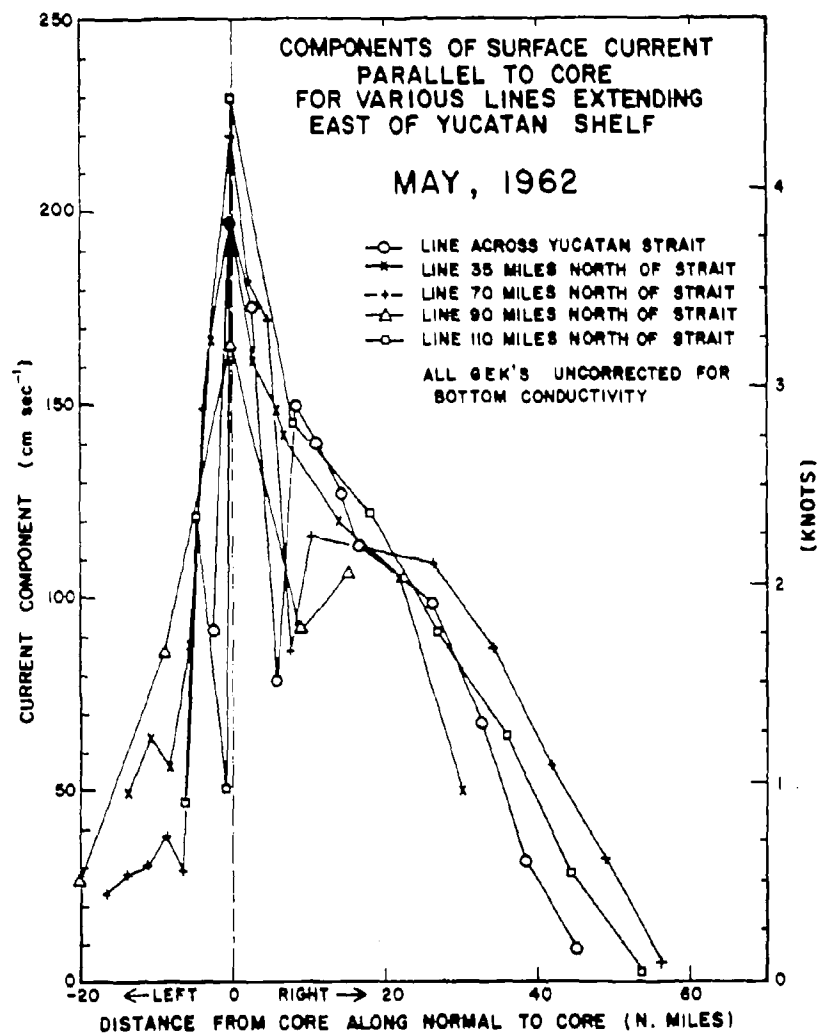


Fig. 2. Surface current profile in May 1962 for various sections at and north of Yucatan Strait.

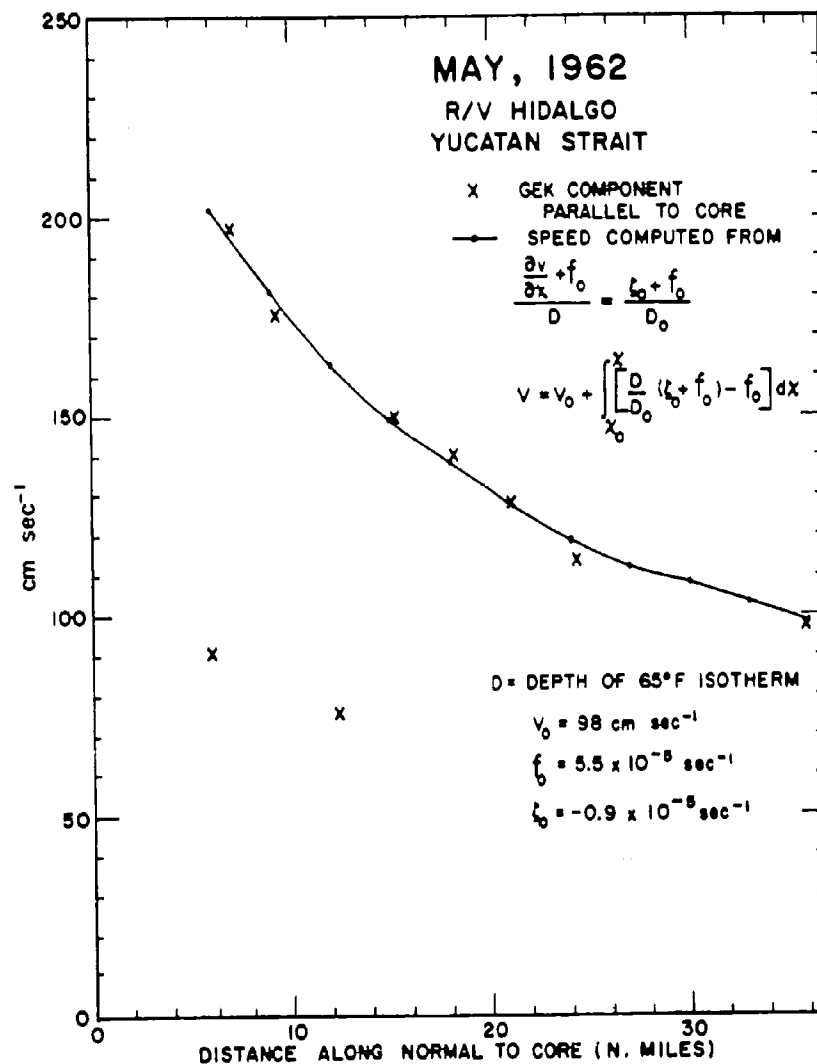


Fig. 3. Comparison of surface current profile based on the assumption of constant potential vorticity across the current with profile observed in May 1962.

was made, moderate. Variations seem more prominent when comparing the weak phases from year to year. In October-November 1962, GEK sections across the current core were made in seven locations between the strait and the north edge of the shelf. These do not exhibit the bands found in the strong phase, although in general there was a single speed maximum. This maximum does not ordinarily follow an isobath. There is no notable agreement between the observed speed profile and that obtained by assuming constant potential vorticity across the stream. The anticyclonic shear on the left (east) of the core is more variable and the cyclonic shear on the right usually broader and weaker than in the strong phase.

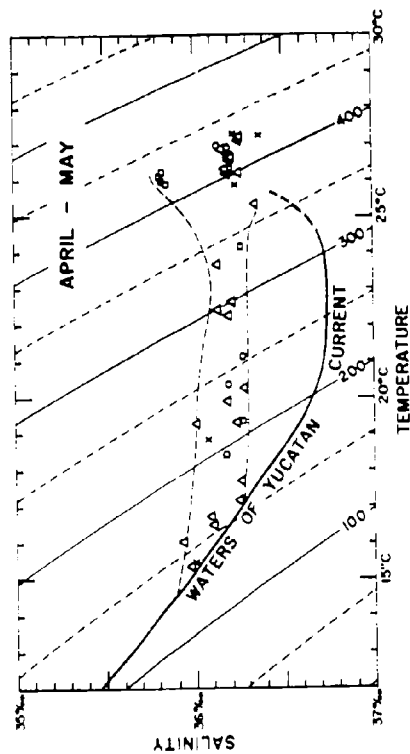
Waters and Thermohaline Structure

On the basis of the May cruises of 1960, 1961, 1962, and certain spring cruises of the Atlantis, each band of the Yucatan Current, when strong, appears to have its own characteristic water and thermal structure in the upper layers. The characteristic differences appear in the occurrence and relative depths of strong, but limited, thermocline and halocline layers. The strong cyclonic shear band left of the current (along the continental slope) is more or less homohaline. In the current proper, thermocline and halocline coincide. In the eddy on the right flank of the current, there is a shallow but marked thermocline below which the shallowest distinct halocline layer is found in a layer of small temperature lapse.

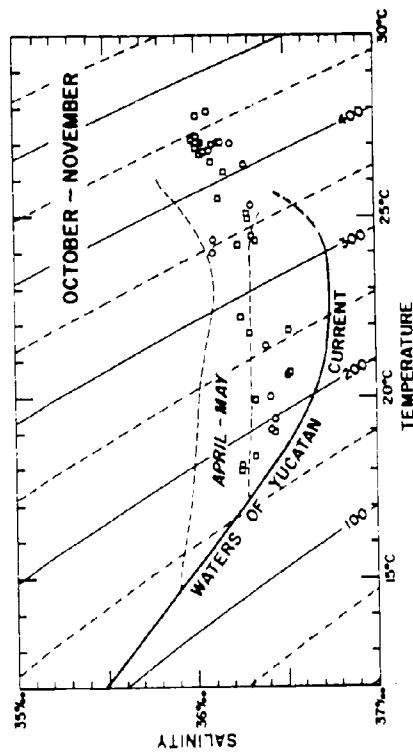
The waters of the cyclonic shear zone are, as noted in last year's annual report, apparently formed by vertical mixing. They undergo appreciable seasonal change as the rather extensive body of data shown in Figure 4A indicates. The water is more or less homohaline in April-May (and later in the strong current season) to temperatures below 18°C. In contrast, the water during October-November has salinities below 23°C which are higher than those of the strong phase (but not so high as those in the Yucatan Current). It is noteworthy that in October 1961, when the weakest currents were encountered, water within active portions of the current had characteristics similar to those in the adjacent slope water.

The waters of the anticyclonic eddy exhibit in spring (and possibly in summer) the traits noted above. Perhaps the distinctions develop because the upper water remains mainly within the eddy, the

WATERS OF EASTERN EDGE OF YUCATAN SHELF



- ATLANTIS MAY, 1933
(1 STATION)
- HIDALGO MARCH, 1961
(1 STATION)
- x HIDALGO MAY, 1961
(1 STATION)
- Δ HIDALGO MAY, 1962
(6 STATIONS)



- HIDALGO OCT.-NOV, 1961
(2 STATIONS)
- HIDALGO OCT.-NOV, 1962
(3 STATIONS)

Fig. 4. T-S correlations of the waters in the cyclonic shear zone for April-May and for October-November.

nearly homohaline layer representing the depth of winter stirring and the homothermal layer the depth of vernal heating, which occurs at much the same time as the strengthening of the current. Similar characteristics are found in some observations in the eddy south of western Cuba, where they may form locally or be brought in from the eddy north of Cuba with which the eddy to the south is often connected. The traits are not apparent in fall, there being then little to distinguish the eddy water from that of the Yucatan Current proper.

Flow in the Eastern and Southern
Parts of Yucatan Bank

In May 1962, when the current was strong, two surface drogues taken in the cyclonic shear zone on the left flank of the core were found to move into shallower water, that is, to the left of the core. (No drogues were observed to move into deeper water.) GEK's agree in indicating flow to the left in five out of seven sections taken in May 1962 and no cases with significant flow toward the core. Since the geopotential at the sea surface over the shelf was lower than at the core of the current, the flow is directed toward lower pressure. This is consistent with the existence of friction in this band of extreme shear.

In October 1962, when the current was not strong, two of three surface drogues taken in the relatively weak cyclonic shear zone moved into deeper water, while the third remained at a constant depth.

Maps of bottom water temperature on the Yucatan Shelf based on BT data have been constructed for the May 1961 and 1962 cruises. In both of these a tongue of lower temperature entered the shallow region near the westward jog in the eastern edge of the shelf. The tongue is not due to a depression in the bottom, the depths of which increases slowly northward. It suggests flow along its axis from the shelf edge toward the west. Such a current would be in agreement with the flow into shallower water noted above. There is a branch of the tongue which turns toward the region of upwelling off Cape Catoche suggesting that the branch is a compensation for the outflow due to upwelling.

Comparison of GEK and Drogue
Measurements of Surface Current

During cruises in May 1961, October 1961, May 1962, and October 1962, eight paired drogue and GEK measurements were made, GEK's and drogues being taken as close together as possible in time and space. The ratio of the drogue speeds to the GEK speeds (the K-factor for the GEK's) ranged from 1.0 to 1.8 with a mean of 1.35. This compares with 1.45 given by von Arx, Bumpus, and Richardson (1955) for perhaps somewhat greater depths off the Atlantic Coast of the United States between north Florida and Cape Hattaras.

B. Investigation of the Currents and Waters off Northeastern Brazil

John D. Cochrane

During March and April 1963, Texas A. and M. made a joint operation with the Hydrographic Service of the Argentine Navy from the Argentine ship LASERRE off northeastern Brazil. Four people from Texas A. and M. participated. The operation was part of the International Cooperative Investigation of the Tropical Atlantic Ocean initiated by the U. S. Fish and Wildlife Service Bureau of Commercial Fisheries.

Figure 5B shows the locations of the 97 serial observation stations taken. Special emphasis was placed on detailed sampling of the upper thermocline layers. Four series of current measurements were made using parachute drogues. Their locations and results are shown in Figures 5B and 6B. Plankton net tows and productivity measurements were taken daily under the direction of Argentine scientists.

Some of the results are almost immediately evident from the data and are presented here in preliminary form. The Equatorial Undercurrent appeared as an equatorial extension of a current settling ESE at the surface. This current had a core of high salinity in the upper thermocline. The upper layers of the ESE current lead apparently from a source region of easterly currents near 7°N, 49°W which was common to it and the Equatorial Countercurrent. But at least as far west as 40°, it was separated from the Countercurrent by vigorous westerly surface flow of the north branch of the South Equatorial Current.

The upper layers of the ESE current reached the equator near 38°W. There was no evidence that the current reached an appreciable distance south of the equator. It simply turned and continued along the equator.

Also near 38°W a retroverse branch from the Guiana Current joined the Undercurrent. Again the turn was very near the equator. The branch brought still more saline water to the Undercurrent. This water appeared to remain somewhat south of the equator, highest salinities occurring at about 1°S at both 37° and 35°W, as Figure 6B shows. Possibly the core of high salinity did not coincide here with the velocity core which presumably lay on the equator.

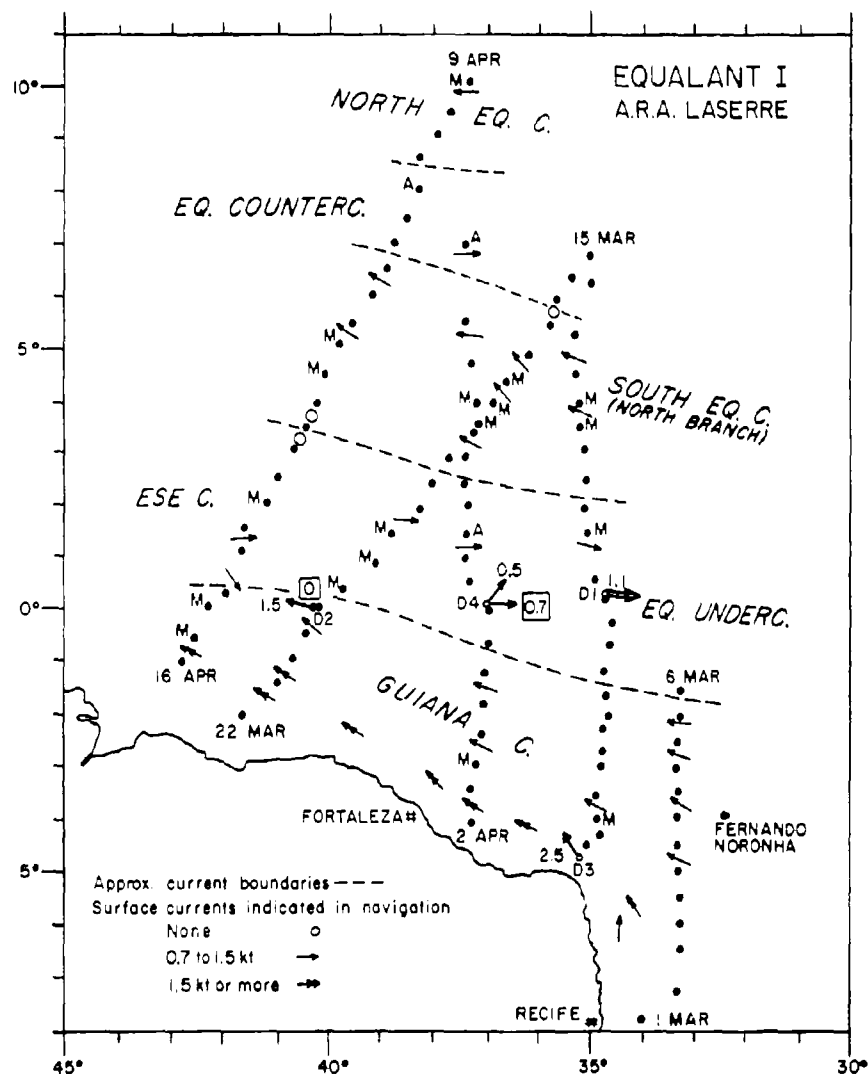


Fig. 5. Current in knots indicated by parachute drogues, designated by D, and by departure from dead reckoning. Speed at 100 m is enclosed in a box. Shear between the surface and 100 m is indicated by an open arrow. Locations are shown where the current of each region was clearly indicated by maneuvering needed to reduce wire angle (M) or by horizontal or vertical wire angle (A).

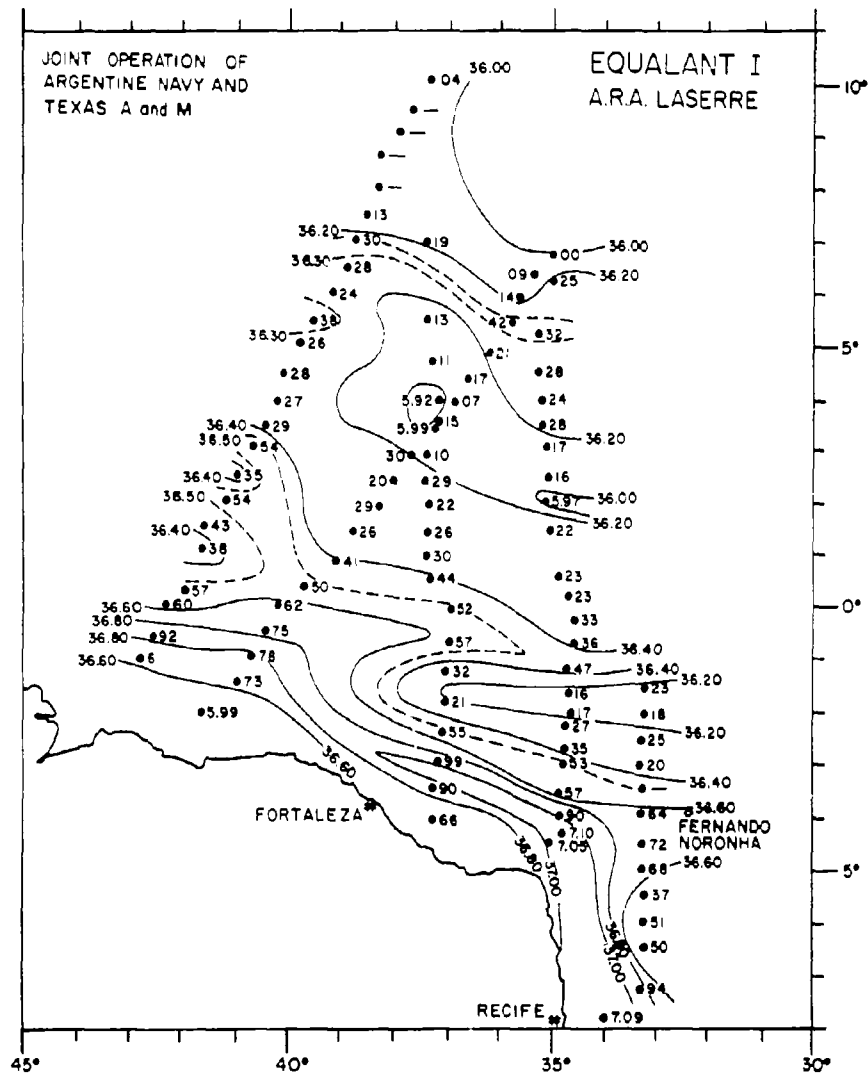


Fig. 6. Maximum observed subsurface salinity in per mille, abbreviated by dropping 36 or 3 in 35 or 37 per mille. Dash indicates a surface maximum.

The drogue series near 40°W presents no evidence of the Undercurrent above 100 m, although it may have been present below. It was clearly present in the drogue series near 37°W, the current at 100 m being toward the east at 0.7 kt while that at the surface was NE at 0.6 kt. (While speeds may be inaccurate, the lower drogue clearly moved faster than that at the surface.) At 35°W the drogue series, taken somewhat north of the equator, indicated a larger shear; the 100 m drogue moved 1.1 kt to the east relative to the surface drogue. Thus the characteristics of flow at the eastern end of the region investigated came closest to being typical of the Undercurrent. However, it should be noted, as shown in Figure 5A, that there was surface easterly flow across the entire region of investigations, apparently strongest between 2° and 3°N.

The salinity maximum in the ESE Current, the Guiana Current, and the Undercurrent was found at depths between 60 and 90 m. This is somewhat shallower than the corresponding core depths of the Undercurrent in the western Pacific.

The source of the high salinity core of the ESE current is not clear. There may be some contribution to the core from the Guiana Current west of 40°W. However, the association between the ESE current and the Countercurrent leaves open the possibility of a northern source. Thus, some of the highly saline water of the Undercurrent may be of northern origin.

It seems noteworthy that virtually all individually described observations taken from February through May indicate a surface current from 7°N, 49°W in what is usually termed the Equatorial Countercurrent, following the ESE setting current described above, and extending east along the equator to 25° or 20°W. Sources of observations are Montgomery (1962), Neumann (1960) and the information outlined above. It appears that in March and April, and perhaps from February through May, there are two bands of surface easterly current extending from a common region near 7°N, 49°W, (1) the Equatorial Countercurrent centered near 7°N, and (2) the ESE and Equatorial Undercurrent. The Countercurrent was rather weak, but present during EQUALANT I. It might easily go undetected in ships' navigation since it would normally influence the ships' drifts less than the prevailing strong NE Trade Winds. East of the Amazon region, the surface easterly flow of the ESE current and Undercurrent would lie in a region of prevailing light winds--somewhat north of the average position of the doldrums.

There seems to be no indication that the Undercurrent or ESE currents exist at the surface in northern summer--in fact, there seem to be no specific observations of the Undercurrent during August. Since responses to changes in driving forces may be large and rapid near the equator, and since seasonal changes in the Trade Winds and doldrum systems are quite large (as noted below), the corresponding changes in the current systems may be expected to be large at the surface and to considerable depths. During EQUALANT II in August 1963, two lines of observations off NE Brazil are planned for another joint operation with the Argentine Hydrographic Office. And to provide basic information for studying the seasonal change, the following work was begun.

C. Seasonal Variation of the Atlantic Trade Wind Regimes

John D. Cochrane

The primary cause of seasonal variation of the Equatorial Currents is doubtless the seasonal variation of the Trade Winds. Since there appears to be no concise, comprehensive description of Trade Wind variation written from an oceanographic viewpoint, this work was begun.

The NE Trade Winds have several centers of mean maximum stress on the sea surface according to mean stress fields for the Atlantic given by Cochrane and Osborn (1950). The stress in northern winter was found to be almost twice as large in March as in October at the strongest center. This center moves from about 7°N, 40°W in March to about 19°N, 50°W in August. Two of the centers have secondary maxima in August, (1) that in the Caribbean between 70° and 75°W and between 15°N and the Venezuelan coast and (2) one in the central Atlantic.

The maximum SE Trade Winds are somewhat stronger than the maximum NE Trades. The strongest center lies about 450 miles off Brazil between 10° and 12°N. Its seasonal movement is small but appreciable. The magnitude of its mean stress increases by a factor of two from March to September.

It is notable that the centers of maximum stress and the doldrum regions of minimum stress linger in their extreme northern or southern positions, but move rather rapidly between them, May and December being the months of largest movement.

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D. Seismic Refraction Studies

John W. Antoine

The results from the seismic refraction cruises on the Continental Shelf south of the Florida Panhandle made during 1961 and 1962 have been evaluated and were presented at the annual meeting of the American Association of Petroleum Geologists on March 25, 1963. The paper was entitled--"The Structure of Portions of the Northern Continental Shelf, Gulf of Mexico, as Determined by Seismic Refraction Measurements." Figure 1D shows the location of the profiles on the Continental Shelf. It has been decided that this data will be readied for publication after augmentation with additional data to be gathered this summer in the area east of Cape San Blas toward the Florida Peninsula. This latter area seems to be the key to the interrelationships between the known regional geology of the northern Florida area and the structure we have detected on the Continental Shelf from our refraction studies.

Figures 2D and 3D show the correlative interpretation between numerous wells drilled in close proximity to the shoreline and the postulated depths to interfaces representing the bottom and top of the Cretaceous over the area covered by our surveys.

Figure 2D illustrates the structure on top of the average 16,400 ft/sec layer which is thought to approximate the pre-Cretaceous surface. Two outstanding features are noticeable: (1) the trough south of the coastline and (2) the rise of the corresponding interface to the east and to the south of the trough. The trough is depicted as paralleling the coast, roughly 40-50 miles offshore, and in its deepest portion contains in excess of 15,000 feet of sedimentary fill. The axis of this trough is roughly aligned to that of the Gulf Coast Geosyncline, more accurately defined in the Texas and Louisiana areas.

Figure 3D illustrates the structure on top of the 10,800 ft/sec interface, which is interpreted as approximating the top of the Upper Cretaceous. The well control onshore was excellent for this horizon and very little extrapolation was necessary. As will be noted, the trough-like feature so well illustrated in Figure 2D loses much of its definition, exhibiting a poorly defined axis. However, the basic trend is still in the same approximate direction.

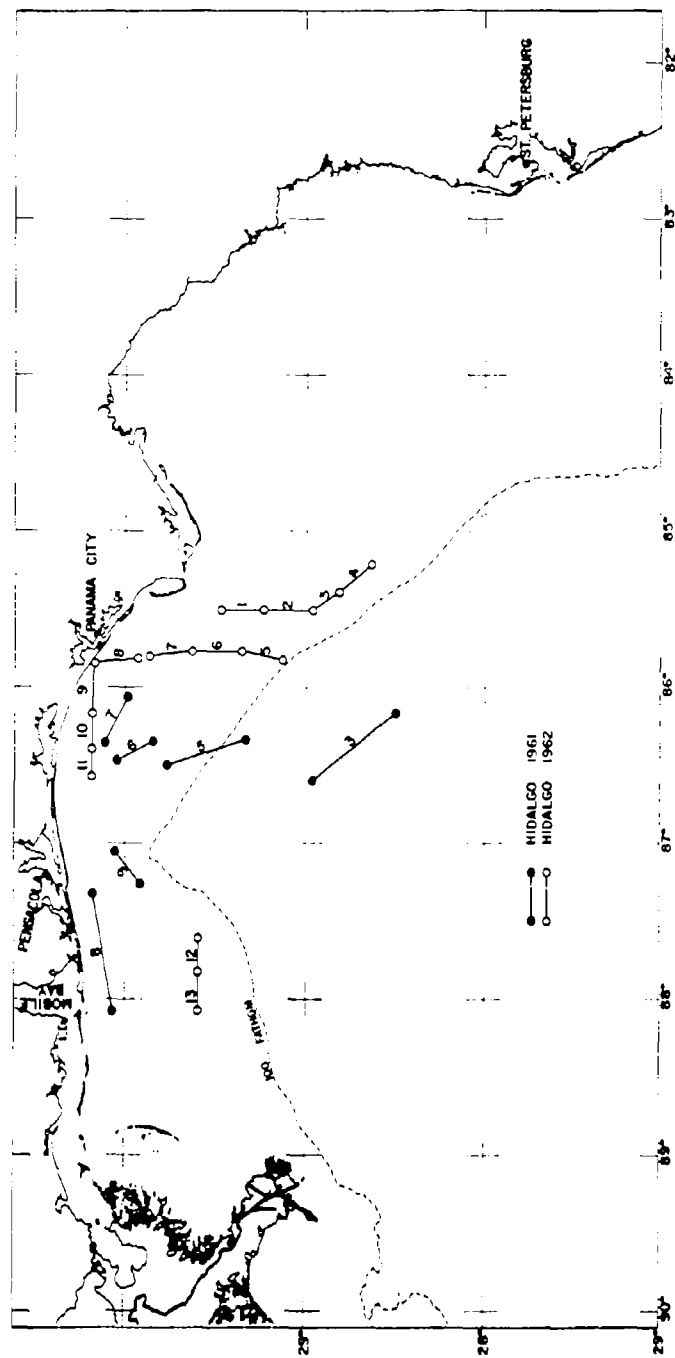


Figure 1D

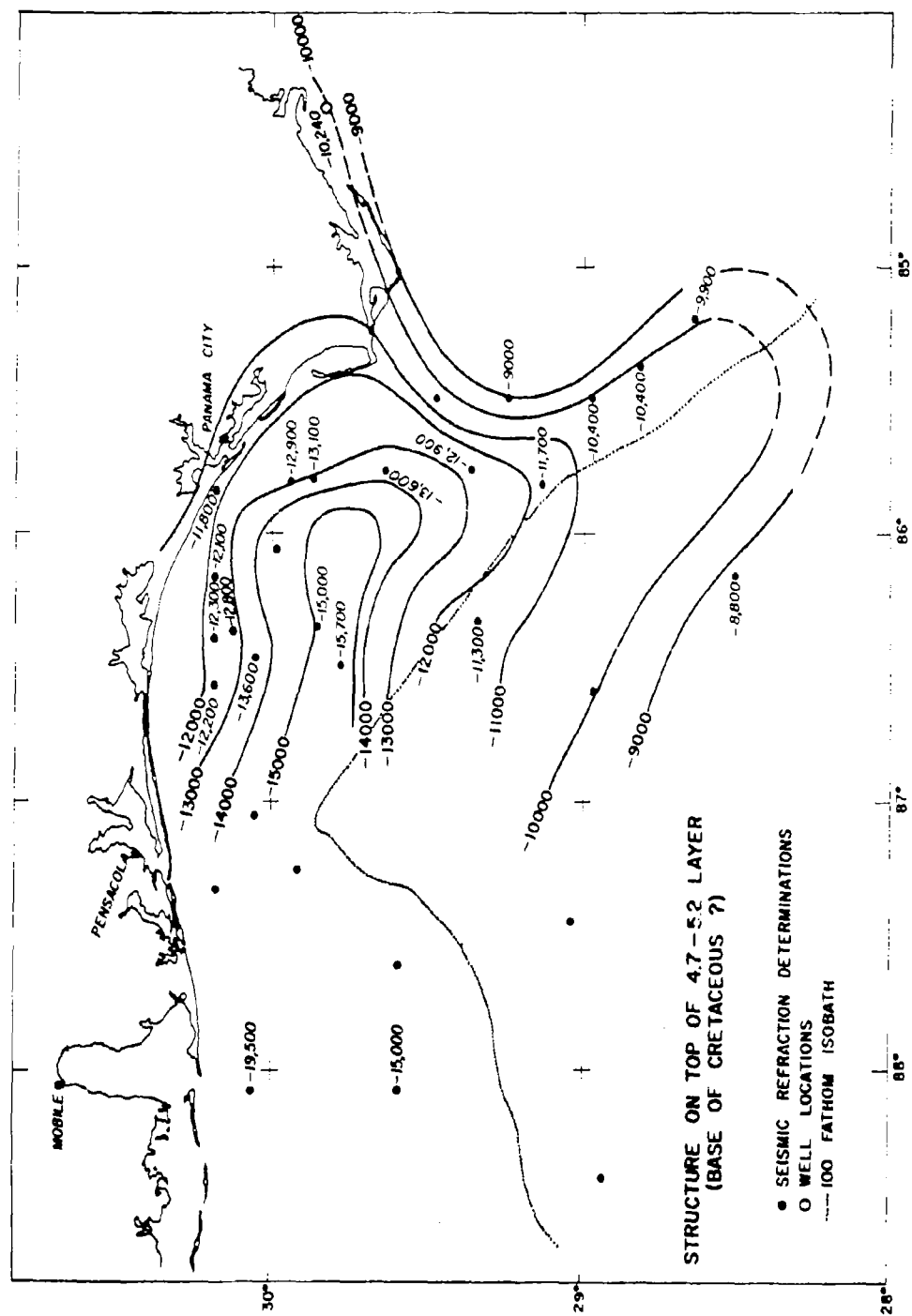


Figure 2D

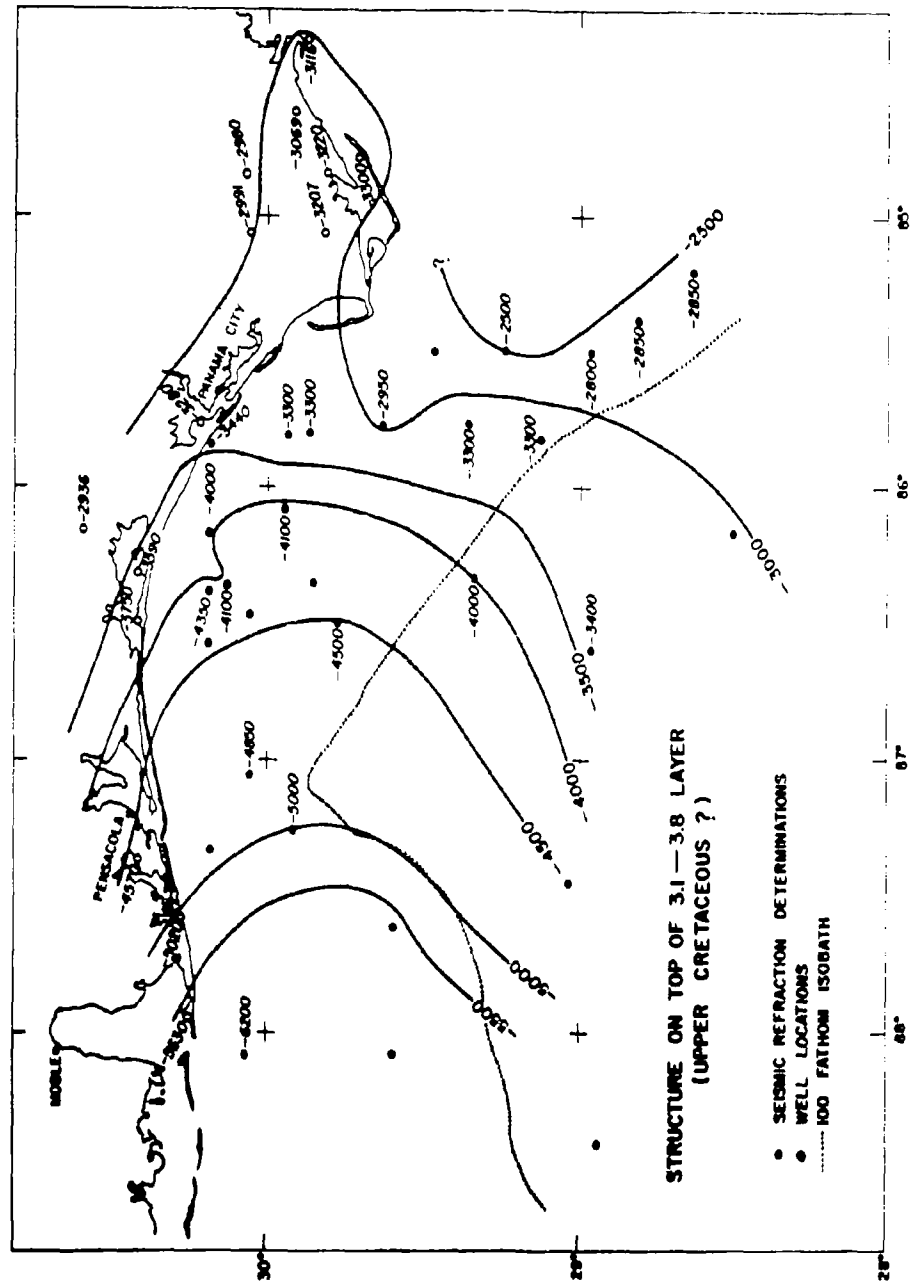


Figure 3D

During December 1962, seismic refraction work was conducted off the coast of Georgia in conjunction with University of Georgia personnel. This data has been evaluated and is being prepared for publication. The offshore results agree quite closely with three nearshore seismic refraction stations, reported by Woollard, Bonini, and Meyer (1957), a few miles from our nearshore station. The survey was extended approximately 60 miles offshore. On all 12 profiles four layers were noted with average velocities of 5500, 8200, 9700, and 19,200 ft/sec. The gross structure of the area covered shows all the beds dipping seaward from the shoreline at about five to ten feet per mile.

Two seismic refraction cruises are planned for this year. The first covered well is the area mentioned above, between Cape San Blas and the Florida Peninsula and the second will cover the area south of Mobile Bay toward the west to the Mississippi Delta. It is hoped that this latter work will determine the western extent of the trough south of the Florida Panhandle and its possible relationship to the Gulf Coast Geosyncline.

E. Environmental Studies off Panama City, Florida

R. D. Gaul

The second contract year of this project has been highlighted by successful automatic recording and reduction of data from Stage I, completion of an internal wave survey jointly with the U. S. N. Mine Defense Laboratory and the Florida State University, installation of a second data acquisition system at the inshore platform (Stage II), completion of a second phase of Savonius rotor current meter investigations, inauguration of a NE Gulf circulations study in cooperation with the Gulf Coast Research Laboratory and incorporation of higher performance tape recorders in the automatic data system. The general development of the project through January 1963 has been summarized in a technical report entitled, "Status of environmental research off Panama City, Florida," A. & M. Ref. 63-2T, 25 January 1963.

The project, in general, is in a state of transition between the development of a research capability and the establishment of individually oriented studies. Several of the latter have taken shape rapidly, especially in cooperation with other projects or organizations, and one graduate research study for an M. S. thesis has been completed (Boston, N. E. J., "The internal tide off Panama City, Florida," A. & M. College of Texas, June 1963). The information given below is intended to briefly update the previously mentioned technical report.

Data System Development

The field data system is now routinely functional with continuous transmissions possible from both of the offshore platforms (Stages I and II). The original Crown 800 audio tape recorders have been replaced with Mincom C-100 units which have 7-tracks for 1/2-inch tape on 14-inch reels. Approximately half of the system's 98 data channels (49 at each platform) are currently in use.

The new "off-line" data reduction system is now in the final phase of construction at College Station. It is anticipated that "debugging" will commence in early June and, hopefully, the system

will be in operation shortly thereafter. Meanwhile, data is being recorded in the field on 1/2-inch tape awaiting readiness of this system. Data that is needed in reduced form in the interim is recorded on the Crown 800 machines and the "on-line" data reduction system is temporarily set up for direct input to the IBM 709. Several runs of this type have been made to provide bottom pressure data for George Austin (USNMDL) and wave data for R. O. Reid (A. and M.).

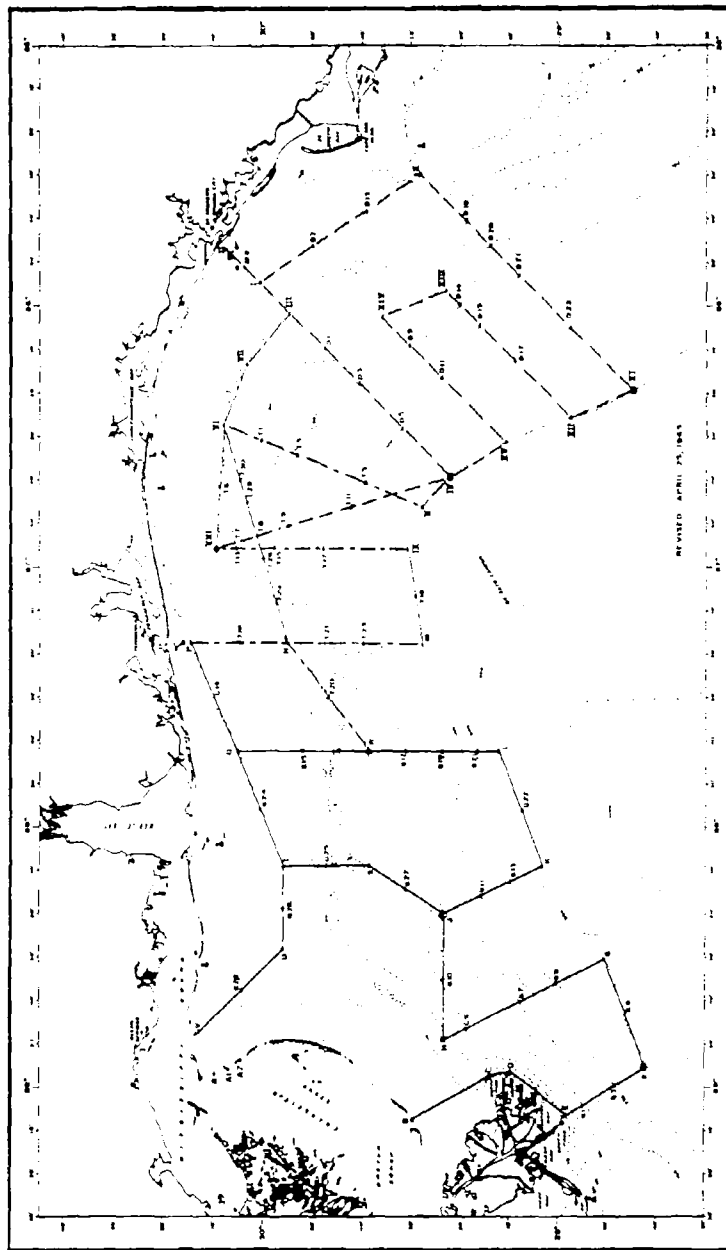
Northeast Gulf Circulation Studies

The cooperative work with Gulf Coast Research Laboratory is progressing well although hampered by weather and equipment problems. Several "shakedown" cruises have been run with the R/V DROGUE subsequent to overhaul of the gasoline engines which was completed in March. The Texas A. and M. steel hull 65-foot "T" boat (VIRAZON) is temporarily operating out of Panama City, partially to assist in these periodic surveys. The first survey involving three vessels (including a "T" boat chartered by GCRL) was attempted during the week of April 29th, following the cruise plan shown in Figure 1E. Weather caused a delay and then curtailed the first leg. The second leg was successfully completed 8-10 May by the two A. and M. vessels and included 24-hour anchor stations at positions VIII and R. The current data have not yet been analyzed but it appears that at Station VIII (head of De Soto Canyon) the currents were both stronger and more variable than has been observed off Panama City at any time. Marked differences in direction were also common between surface, mid-depth and bottom measurements.

Future 3-ship surveys are scheduled for 27 May-1 June, 27 June-2 July and 5-10 August. The VIRAZON will return to Galveston in August and the cruise plan will be modified for 2-ship coverage at 4 to 8 week intervals.

Internal Wave Studies

A technical report will be prepared covering the internal tide investigations by N. E. J. Boston. This work will be amplified somewhat based on analysis of surface tide records from Stage I, a pier inshore from the Stages and a pier located at Destin, about 38 miles to the west. The main experimental basis for the internal



NORTHEAST GULF OF MEXICO SURVEY PLAN I
REVISED APRIL 25, 1945
OFFICE OF THE CHIEF OF NAUTICS

Figure 1E

tide study was a 3-day survey in June 1962 of a 10-mile square centered on the Stages. Analysis of the BT data was not yet complete when Mr. Boston's thesis was written but his analytical method largely circumvented this difficulty. A paragraph from the conclusion of Mr. Boston's thesis is quoted below:

"The tidal wave is believed to be a progressive wave moving parallel to the shore to the northwest. The internal wave motions can be explained by a) standing waves in a three-layer system oscillating perpendicular to shore and 180° out of phase with the surface wave, or b) an internal Kelvin wave. If case (a) is true, the wavelength of the standing wave is about 22 miles. Field observations to check the validity of this hypothesis are suggested. Case (b) requires that the surface wave also be of the Kelvin type. Further field and theoretical investigations are necessary to check this hypothesis."

Multiple level current speed data collected automatically at Stage I during the June 1962 survey reveal short term high speeds (an hour or less at speeds up to 1.2 knots) at individual depths. If these are real, i.e., not related to equipment malfunction, they must be related to internal motions since they do not correspond to tidal modes and surface waves were nil during the survey period. These and other data from the survey will be analyzed this summer in co-operation with George Dowling, Garry Saleman and William Tolbert of USNM DL.

One of the products of the periodic NE Gulf surveys will be an estimate of the mean horizontal distribution of density structure over the shelf. This is essential to extension of Boston's work and to interpretation of time series observations made at the Stages. Results thus far are scanty but indicate that layers are neither horizontally homogeneous in terms of temperature, nor do the isotherms slope in a linear or smoothly curvilinear fashion offshore. Considerable longshore variations are probably to be expected, especially in the vicinity of De Soto Canyon.

Istiophorid Fish Studies

The work by N. G. Vick on the morphometrics of Gulf istiophorids, particularly the Atlantic sailfish, Istiophorus albicans, has been summarized in a technical report which was printed in

June. There seems to be evidence to substantiate a hypothesis that these animals are environmentally isolated that appear in the northeast and northwest sections of the Gulf during the summer and early fall months. Another point of interest is the spawning habits of the fish as related to the environment off Panama City, which will be an area of major concern in field studies this summer.

F. Geological Oceanography

Louis S. Kornicker

The year's activities in Geological Oceanography were summarized in a technical report, Reference 63-10A to the same distribution as this report. Therefore we quote here only the context of said report.

"Carbonate sedimentation and environments on the
Mosquito Bank, Nicaragua-Honduras

by Louis S. Kornicker

"Regional aspects of carbonate sedimentation, Campeche
Bank

by Brian W. Logan

"A study of the lithic calcarenite suite of the Campeche
Bank

by James L. Harding

"A study of the Campeche calcilutite of Wisconsin age

by Wayne M. Ahr

"A study of the pelletal and oolitic calcarenite suite of the Campeche Bank

by Joseph D. Williams

"A study of the off-reef clastic suite at the Arcas group

by Robert G. Snead

"A study of the zoogeography of the molluscan faunas of the Campeche Bank

by Mrs. W. Rice and Louis S. Kornicker

"Detailed mapping of the reef biota, Arcas reef group

by Louis S. Kornicker

"Wave refraction at the Arcas reef group, Campeche Bank

by Donald E. Walsh

"Reef instrumentation study

by Jack O. Hill

"Beach studies at Cayo Arcas

by Louis S. Kornicker

"Reconnaissance study of the moat, Cayo del Centro

by Louis S. Kornicker

"Physical oceanography of the Campeche Bank

by Louis S. Kornicker"

G. Chemical Oceanography and Geochemistry

Donald W. Hood

The work in these areas during the contract year centered on the continuation of the work on carbon dating and in the organic chemistry of sea water. In addition, work on the ratios of alkaline earth metals in sea water and collection of large samples for trace metal and trace organic analysis by a deep water pumping system was initiated.

Radiocarbon Dating of Sea Water. Kenneth Briggs

During Cruise 62-H-13 of R/V HIDALGO from October 8 to 17, 1962, several samples from different depths of the Sigsbee Deep were collected for the following reasons: (1) to determine relative age of water from different depths by means of inorganic CO_2 dating and (2) to determine age of organic matter in ocean water by C^{14} dating.

The system for collection of CO_2 for determination of inorganic C^{14} content consisted of a 30" x 10' high fiberglass tank provided with a conical bottom fitted with a valve and a flat top that was sealed to the tank by means of a gasket and 0.25" steel bolts. The top was provided with three entry ports for addition of chemicals and removal of gases. The water was brought to pH of 2 by addition of H_2SO_4 . To collect gases two diaphragm air pumps hooked in series were used to circulate gases evolved from 200 gallons of acidified sea water through an absorber containing KOH held in steel gas collecting bottles. The gas was recycled through the water for approximately four hours in order to absorb the CO_2 released.

Dating of the organic matter of sea water is of considerable importance if we are to understand the cycling of the dissolved organic matter of the ocean. To accomplish this, 5-8 grams of organic carbon must be isolated free of the inorganic forms. Since the concentration of carbon is between 1-3 mg/L of sea water it becomes necessary to develop special techniques to sample, isolate, and collect the carbon dioxide from organic matter. Since the volume of water needed is 1000-2000 gallons and this must be pumped from the bottom

of the oceans (about 12,000 feet in the Sigsbee Deep) a considerable number of equipment innovations were necessary. Most of the equipment needed for this work has been assembled and four samples were collected on Cruise 62-H-13. Counting will be accomplished this year.

Four dates of inorganic carbon were obtained for water from the following depths: 20 feet, 600 meters, 1000 meters and 3400 meters. The benzene synthesis method developed at A. and M. by Noakes, Isbell, Stipp and Hood (1963) was utilized in dating these samples.

The results obtained (Table IG) were surprising, and they shed considerable insight into probable origin of waters contained in the Sigsbee Deep.

TABLE IG

Sample Depth	C ¹⁴ Date
10 feet	-83.2 (+97, -93 years)
600 meters	702 (-63, -91 years)
1000 meters	764 (+126, -75 years)
3400 meters	519 (\pm 76 years)

If these dates are correct then the bottom waters of the Gulf of Mexico are considerably younger than most workers had thought and also the deep water must slowly rise and mix with the intermediate and finally surface waters before leaving the Gulf of Mexico. Further analyses of this type are needed both to substantiate results reported here and to further delineate the origin of water masses in the Sigsbee Deep. The results need substantiation in larger areas of the Gulf of Mexico and this will be done on samples collected on the R/V ALAMINOS during regular cruise schedules this year.

Lipids in Sea Water. Lela M. Jeffrey

On Cruise 62-H-13 of the R/V HIDALGO from October 8-17, 1962 an attempt was made to extract lipids from acidified sea water with petroleum ether on a pilot plant scale by liquid-liquid extraction in a packed column 6" in diameter and 6' tall. The purpose of this operation was to obtain a large enough lipid sample to be able to characterize more adequately the many solvent soluble compounds present in sea water in trace amounts.

One thousand gallons each were extracted in the system from depths of 3400, 954, and 10 m in the Sigsbee Deep. The water was pumped from the various depths with the jet pump system described later, through a millipore filtering system, into an acidifying tank, then into the extraction column in countercurrent flow with previously distilled petroleum ether held in a storage tank. The extracted sea water (or raffinate) was dumped overboard after volume measurements. The extract or petroleum ether phase was pumped to the petroleum ether still where the lipids were concentrated. The distilled petroleum ether was, of course, re-circulated to the extraction column. The concentrated lipids and remanent petroleum ether were periodically removed from the still and stored for further processing in the shore laboratory. Several blanks were also run to test for contamination in the extraction and distilling systems.

In the shore laboratory at College Station, these extracts of thousand gallon samples of sea water were concentrated to a few milliliters and characterized by silicic acid column chromatography, thin layer chromatography, and infrared absorption studies, as described in a paper by Jeffrey, et al. (1962). Unfortunately, it was noted that the blanks were higher than was considered desirable. Attempts are now being made to separate and/or analyze the contaminants from the sea water lipids.

Valuable experience and information were obtained from this pilot plant operation, and a refined pilot plant is to be tried in the near future.

In addition to the pilot plant studies, filtered water samples were collected in 8-liter polyethylene samplers on a hydrographic cast and extracted with petroleum ether in large separatory funnels. The extracts were characterized by separation into lipid classes on silicic acid columns, then chromatography of the classes on glass

plates coated with silica gel. From these studies it is evident that there are hundreds of lipid compounds in sea water in trace amounts, including hydrocarbons, sterols, fatty acids, tri-glycerides, mono- and di-glycerides, phospholipids and other unidentified constituents (Jeffrey, et al., 1962). The significance and origin of these materials will take much time and effort to fully evaluate.

Miscellaneous Studies

Fifty to sixty gallon samples of sea water from Sigsbee Deep were processed from each of the depths: 10, 600, 954, and 3400 m for amino acid and protein analysis. This was accomplished by ferric hydroxide co-precipitation in fiber glass tanks with a conical bottom. Measured quantities of known carbon-14 labeled amino acid mixtures were added to each sample, so that more exact concentration data for each amino acid could be obtained. These samples are being analyzed at the present.

Distribution of Mg, Ca, Ba and Sr in Sea Water. S. Sommer and E. E. Angino

The concept of constancy of composition of sea water has been a favored tenet of oceanography for many years. Recent studies, however, have suggested that the distribution, both vertically and horizontally of magnesium, calcium, strontium and barium may not be quite as constant as heretofore believed.

To check this hypothesis 100 and 500 ml water samples were collected by U. S. Coast and Geodetic Survey on a track from Norfolk, Virginia to Vieques Passage Area, Puerto Rico. Samples were taken at 12 stations spaced approximately 90 miles apart. Sample depth ranged from surface to greater than 5000 meters. The analytical procedures employed for determination of Ca^{2+} , Mg^{2+} , Sr^{2+} , and Ba^{2+} is described briefly below.

Separation of Mg^{2+} , Ca^{2+} , Ba^{2+} and Sr^{2+} was obtained by use of ion exchange techniques (with modifications) described by Tsubota and Kitano (1960). The exchange columns were constructed of 50 ml ultramax Burettes connected to a 125 ml separatory funnel. The columns (11 mm width) were filled with Dowex 50 x 8, 100-200 mesh

cationic exchange resin to a total height of 10 cm; flow rate was controlled to 2 ml/m by proper selection of packing supports (here 1/8" glass beads and glass wool) and by manual control of the burette stop-cock. The resin was prepared in H^+ form by addition of $4N$ and $1.5N$ HCl .

A 20 ml sea water sample is placed on the resin and elution follows with: pH-4 ammonium formate-formic acid buffer to elute Mg^{2+} , pH-4.1 of same buffer to elute Ca^{2+} , pH-4.4 buffer for Sr^{2+} and a 2M ammonium formate solution to elute the Ba^{2+} .

Ten ml samples were collected and analyzed for Ca^{2+} , Mg^{2+} , Sr^{2+} , and Ba^{2+} with 0.01 EDTA using phthalein complexone as indicator. Eirchrome Blank T was used as an indicator in the titrations. Ca^{2+} , Sr^{2+} and Ba^{2+} were titrated to a fading red to colorless endpoint and Mg^{2+} was titrated to a blue endpoint at 50-60°C.

Some of the problems encountered are the following: (1) difficulty in separating Sr^{2+} and to a greater extent Ba^{2+} with present column design. This will probably necessitate a modification of column design to admit a greater amount of water sample, (2) difficulty in getting a clear end point with phthalein complexone as the carbonates may precipitate out at some of pH's used, thereby obscuring the endpoint. This problem may be eliminated by removing CO_2 from the water and carrying out a back titration.

Test runs using standard solutions indicate that results for Ca, Mg and Sr will be determined with maximum errors approaching $\pm 0.5\%$ for Ca and Mg and $\pm 3.0\%$ for Sr.

Trace Element Analysis of Suspended Material

Over 1000 gallons of sea water from each of four separate depths were pumped through 0.45 millipore filters and the filter cake examined quantitatively by emission spectrography for trace element content. Preliminary results are presented in Table IIG.

Rough calculations indicate that the Fe content at 1000 m represents approximately 1 ppm. The other constituents can be related to this figure.

TABLE IIG

Order of Abundance in per cent, Sigsbee Deep Samples*

93°53'W, 24°27'N

Element	Depth 10 M**	Element	Depth 600 M	Element	Depth 1000 M	Element	Depth 3400 M
Fe	23.60	Fe	34.50	Fe	40.70	Fe	36.50
Ca	3.90	Ca	3.20	Cu	2.50	Ca	3.20
Mg	3.50	Mg	2.30	Ca	1.80	Mg	2.30
Na	3.00	Na	1.80	Mg	1.00	Cu	2.00
Zn	0.80	Zn	0.90	Zn	1.00	Na	1.80
Al	0.70	Al	0.60	Al	0.40	Zn	1.10
K	0.30	Pb	0.32	Sn	0.40	Al	0.40
Cu	0.20	K	0.20	Na	0.20	Sn	0.27
Sn	0.20	Cu	0.20	Pb	0.20	Pb	0.30
Ti	0.10	Sn	0.11	Mn	0.040	K	0.20
Mn	0.10	V	0.10	Cr	0.040	V	0.090
Pb	0.10	Mn	0.050	V	0.070	Cr	0.040
V	0.060	Cr	0.020	K	0.030	Mn	0.030
Cr	0.040	Ti	0.020	Ti	0.020	Ti	0.020
Sr	0.015	Sr	0.010	Sr	0.010	Sr	0.010
Ba	0.010	Ba	0.007	Ba	0.007	Ba	0.007
Ni	0.008	Ni	0.003	Ni	0.003	Ni	0.004
Mo	< 0.001	Mo	< 0.001	Mo	< 0.001	Mo	< 0.001

Looked for but not detected (semi-quantitative analysis) Bi,
Zr, Sb, W, Cd, Li, Nb.

*As per cent of material making up filter cake.

**M = meters

Analyses by Quantitative Emission Spectroscopy

X-ray diffraction studies of filter cake material using appropriately filtered Cu K α and Fe K α radiation gave negative results. This suggests that material is in either colloidal or in a microcrystalline form. Qualitative tests suggest the former is more likely.

Petrographic Study of Filter Cake Material

Treatment of filter cake material from all depths with dilute HCl left a small insoluble residue of flaky appearing black particles (detritus). These apparently are pieces of carbon (possibly graphite).^{*} Microscopic studies using oil immersion techniques shows that these particles will sink in a drop of heavy liquid having a gravity of 1.8, but do not sink in a liquid with a gravity of 2.7. Particles will neither float nor sink in a mixture of these liquids with a gravity of 2.3, but tend to remain in motion in the liquid. Further evidence of carbonaceous character of material is the fact that individual grains disappear on combustion to a red heat leaving only a fine white ash.

Intermixed, sparsely, with black opaque flakes are clear angular quartz fragments suggesting wind transport. The black shards are angular with globular outline that resembles organic detritus. A very few red flakes resembling feldspar particles were present, although they are probably not feldspathic material.

Size of black flakes ranges up to 1 mm with an occasional flake twice this size. Some of the flakes (~30%) are slightly soluble in some of the standard organic solvents (xylene, petroleum ether, chloroform) but not in others (toluene, methanol, isopropyl alcohol, etc.). Sulfuric acid and 30% H₂O₂ does not affect remaining material, suggesting again the possibility of flakes being graphite.

None of the flakes are magnetic, they are fragile and break easily under a sharp edged tool. Study of these particles is continuing.

^{*}For their aid in identification of some of the suspended material, we wish to acknowledge the U. S. Bureau of Mines, Rolla Metallurgy Research Center, Rolla, Missouri.

Large Deep Water Sample Collection by Pumping

To conduct some of the work previously described, it was necessary to collect uncontaminated water samples from all depths of the ocean in quantities of 1000 gallons or more. Since this water was to be processed aboard ship in continuous or batch equipment, a volume of between 10 and 20 L/min was considered sufficient for our purposes. To accomplish this, advantage was taken of the jet principle employed in delivering water from deep wells for household use in rural areas of the country. The pump functions by cycling a large volume of water under high pressure through a jet which is placed below the water level. It is capable of producing pressure drops at the jet equal to the hydrostatic head of the water surrounding it. If the jet is placed 300 feet under the surface of the sea, a pressure drop of 10 atmospheres (150 psi) between the intake of the sample port and the jet could theoretically be developed before cavitation of the water would occur. Since between three and four hundred feet is a reasonable working depth for the 2 H.P. electric jet pump we only needed to find a tubing or pipe which would sustain a pressure drop of 150 psi in the desired lengths and diameter to deliver the volume of water desired aboard ship. We concluded that a delivery of 10 liters of water per minute from a depth of 12,000 feet would be sufficient to supply our needs for the continuous processing systems we planned. Calculations indicated that 3/4 inch I.D. tubing would deliver this quantity of water, and it was found that linear polyethylene obtainable in 1,000 foot lengths at a cost of \$0.07/ft would readily withstand the pressure drop involved. Data concerning the large sample pumping system and the pumping rates obtained at different depths are presented in Table III G.

In this system certain advantages are realized over other large sampling devices in that all moving parts of the system are aboard the research vessel; when not in use the entire assemblage is easily stored and handled for prolonged periods of time without much likelihood of damage. The system is all plastic except for the metal jet and the pump body proper, and because of the large volume of water being moved, contamination from these sources is limited. The equipment necessary for pumping from 12,000 feet is available commercially or may be constructed for about \$1400, including the plywood reels for holding the tubing and clamps for use on the hydrographic cable. The chief disadvantage is the time required for pumping large samples and thus a fairly high ship cost is involved. However, if maximum use is made of the water brought aboard, ship time may be easily justified in terms of the value of the results obtained.

TABLE III
Large Sample Pumping System

		Supplier			
Pump	2 HP 220V 3 phase Jet Type	Sears & Roebuck			
Tubing	0.810" ID Linear Polyethylene 12,000' in 1000' rolls	Hudson Extrusion Co.			
Weight tubing	75 pounds/1000 feet				
Depth of Jet	300 feet				
Pumping Rates	10 meters 25 L/min	600 meters 20 L/min	1000 meters 15 L/min	3400 meters 10 L/min	

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H. Currents and Water Masses in the Gulf of Mexico

Hugh J. McLellan

The data from the spring 1962 survey has been under continuing study, mainly by Mr. Worth D. Nowlin, a graduate student, who joined the project staff after the end of the fiscal year. The deep waters have been shown to be extremely uniform with respect to temperature and salinity. Statistical treatment of the data by machine methods shows that in the deep water it is possible to generate simple polynomial functions for potential temperature and salinity versus depth which fit the data with astonishingly small standard errors. These show a slight positive stability in the basin. A report on this and on the unexplained horizontal variation of dissolved oxygen is in press.

Mr. Nowlin has prepared computer programs to examine objectively the data from this survey and existing earlier data with regard to circulation within the Gulf waters. Preliminary results indicate that a much less complex flow regime than heretofore postulated may characterize the surface layer circulation.

I. Sampling Organic Structures in Tidal Flat Deposits

Robert E. Stevenson

Burrowing organisms have a great influence on the sediment structure of marine deposits. Where the infauna is composed of many individuals, depositional layers are usually absent below the top few centimeters. Where bottom conditions are inhospitable to benthic organisms (high salinity, anaerobic waters, etc.), surface ripples, graded bedding, micro and macro-laminations are preserved; in some cases, through many hundreds of feet of sediments.

In tidal flat deposits, the abundance of organic debris is usually great enough to produce highly acidic muds (Stevenson and Emery, 1958). As a consequence, the calcareous endo and exoskeletal material of marine organisms is dissolved leaving, if anything, only casts and molds of the animals. However, all benthic animals, whether of the epi or infauna, make tracks, burrows, tubes, and excretal material which differ enough to allow at least generic identification of the animals.

The study of the modes by which organic remains are preserved in marine sediments was given the name of Aktuopaläontologie by Rudolf Richter in 1929. Dr. Richter was, at the time, director of "Senckenberg am Meer" in Wilhelmshaven, Germany. Since that time, detailed investigations have been conducted, mainly in the Jade Bucht, by Dr. Wilhelm Schäfer and Dr. Hans-Erich Reineck (present director). Dr. Schäfer worked with the animals and Dr. Reineck with sediment structures; the study of which he calls Aktuogeologie. The culmination of Schäfer's work has been the publishing of a book (in 1962) on his many analyses of Aktuopaläontologie.

Investigations similar to those conducted at "Senckenberg" are unknown in the United States. Because each species, or at least genus, produces a distinct burrow, track or tube, it was considered that analyses of these various organic structures would be valuable in the identification of paleo-deposits and facies. In February, 1963, therefore experiments were begun on tidal flat deposits in Galveston Bay, using a modified Reineck-sampler (Figure II).

To obtain a sample the sampler (a simple metal box, open at

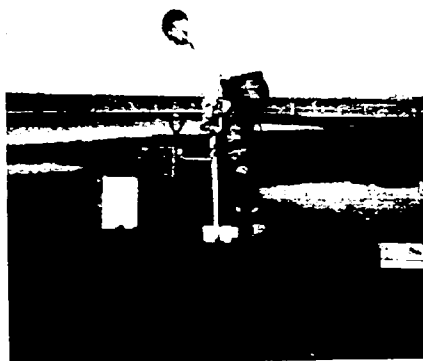


Figure 1 I



Figure 2 I

each end and held together with screws) is forced into the sediment. Once it has reached the required depth, the mud is dug away from the side (Figure 2I) and a bottom plate is shoved in place. The plate is held by two springs hooked over the top of the sampler (note in Figure 1I).

In the laboratory, the sample, still in the box, is dried in an oven at temperatures less than 100°C. The time required varies from one to three days depending on the sand content of the sediment (greater sand, less time). Once dried, the samples can be removed from the box and made ready for study (Figure 3I).

The features of the sediment structure are noted by cutting through the sample with a large knife or spatula. Where interesting features are seen (as the Tagelus burrow shown in Figure 3I, and the siphon and worm tubes in Figure 4I), photos may be taken, or the sample preserved with paraffin (Figure 5I), or plastic (Reineck, 1961). Each method of preservation has its advantages. With paraffin, the three dimensional aspect of the sediment is obtained and individual layers may be removed for mineral-grain analyses, or whatever. With plastic, the same features are preserved, but the sand grains are permanently cemented. However, in this case, a piece of the sample may be cut away and thin sections made for detailed examination.



Figure 17



Figure 47



Figure 57

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J. Modification of Water Temperatures by Hurricane "Carla"

Robert E. Stevenson

The most dramatic and intense interaction between the sea and the atmosphere takes place during the full hurricane. These monstrous storms draw from the sea the awesome quantities of energy required to sustain them through their short but violent lives.

Because the energy exchange is several orders of magnitude greater than that in the more usual tropical storm, hurricanes provide a unique 'laboratory' for investigations of air-sea interaction. The taking of *in situ* measurements of water temperature changes is, however, virtually impossible. Aboard ship, nothing can be done but to practice survival techniques, and even these are unsuccessful on many occasions. Weather buoys have been broken from their moorings, never again to be seen, and towers have foundered.

To obtain data of changes in the sea caused by hurricanes is, then, of great interest. This was made possible in the northwest Gulf of Mexico by a fortuitous set of circumstances following Hurricane "Carla."

"Carla" entered the Gulf through the Yucatan Straits on September 7, 1961. From there it travelled in a northwesterly direction and grew into one of the five severest hurricanes to invade the Gulf since 1837. By September 10, as it approached the Texas Coast (Figure 1J), pressures in the center reached a low of 27.50" (931.2 mb), and winds of 130 knots whirled around the eye. Because of the early and continuous advisories issued by the U.S. Weather Bureau, nearly 500,000 people evacuated the coastal regions. Thus, despite the fury of the winds and the rising storm tides (a maximum of twenty-two feet where the storm crossed the coast), the loss of life was minor.

The path taken by "Carla" into the northwest Gulf was fortunate from the viewpoint of investigating its influence on the sea (but from no other, presumably), for it crossed an unusually extensive bulge of brackish water. Normally, a low-salinity layer of water lies along the Texas Coast where river water emanates through the estuaries and lagoons. In September 1961, this brackish

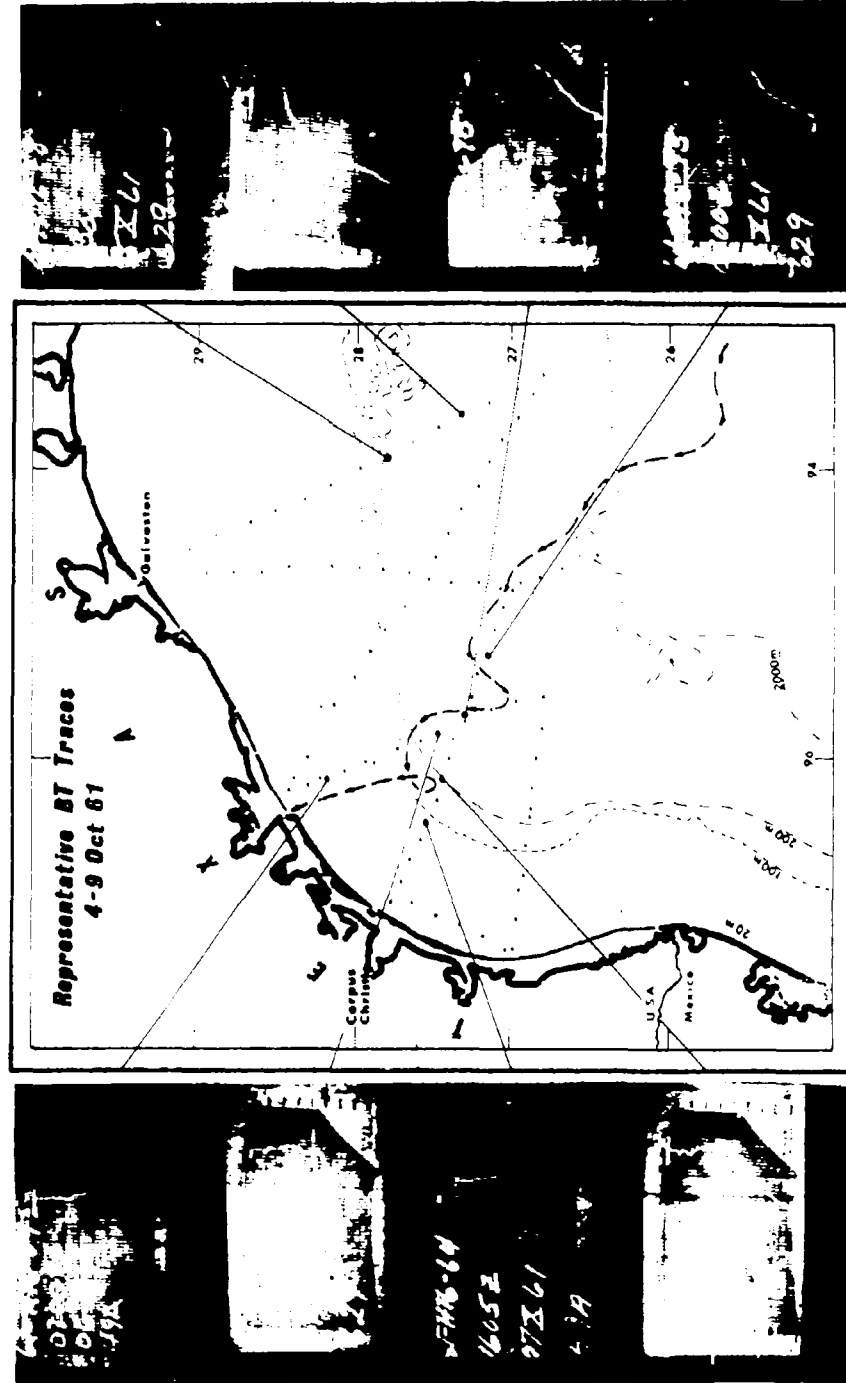


Figure 1J

layer extended 120 nautical miles from the coast between Brownsville and Galveston, Texas. Salinities ranged from a low of 29.76 ‰ at the surface; through 30.00 ‰ at 40 meters; to 35.00 ‰ at 70 meters. Waters with normal salinities at 36.50 ‰ lay below 100 meters. Hurricane "Carla" swept over this bulge of coastal water on September 10-11.

A month later, when scientists from the A. and M. College of Texas cruised in the northwest Gulf aboard the R/V HIDALGO, many of the traces from their bathythermograph casts revealed impressive temperature inversions (Figure 1J). Temperatures in the upper water layers were as much as 2.5°C less than in deeper waters, and the inversions extended to a maximum depth of 83 meters. It seemed apparent that the heat lost from the sea during the passage of "Carla" formed the inversions, and that they were "preserved" because of (1) the low-salinity surface layer, (2) negligible heating after the hurricane, and (3) an absence of appreciable lateral exchange in the month following.

Where salinities were more typical of Gulf waters (36.50 ‰), southeast of Galveston, the heat loss from the surface caused instability in the upper layers. As a result, convective stirring formed an isothermal layer of water which extended to depths of 60 meters (Figure 1J).

From the distribution and magnitude of the temperature inversions, it was possible to calculate the heat lost from the sea to the hurricane during the 24-hour period from 1200, September 10 to 1200, September 11. The volume of water involved in the energy exchange was determined by examining the depths to which the cooled surface waters extended. The distribution pattern of the depths (Figure 2J) shows that the greatest depth of influence was in the area where the hurricane deviated from its northwesterly course. Inversions were measured as close as one mile from the shore in the vicinity of Corpus Christi. To the east, inversions were not present in the waters where normal salinity distributions occurred, and inversion depths shoaled abruptly at the boundary between the two water units.

To determine the temperature ranges in the inversions, the bathythermograph traces were examined and a rational projection of each trace was made. The distribution of temperature ranges differed from the inversion depths. The greatest differences were

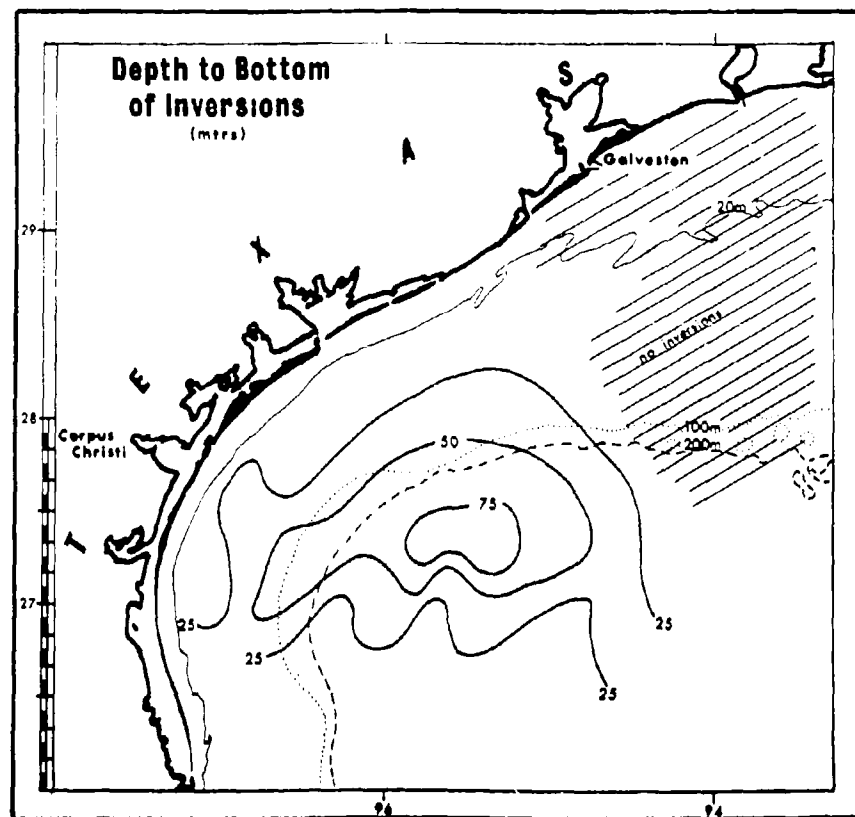
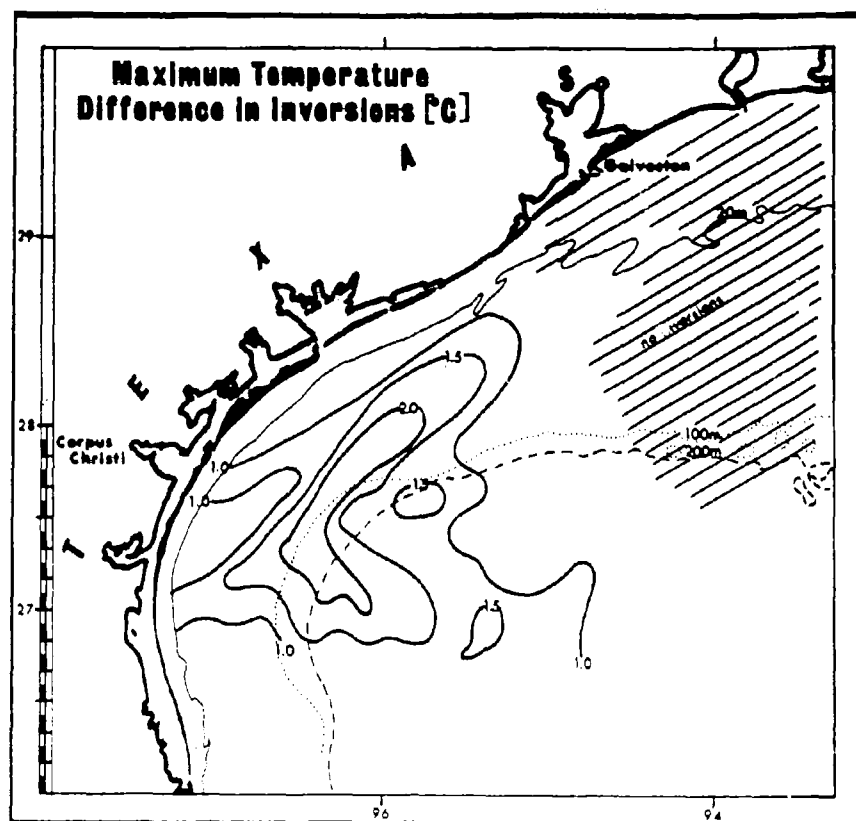


Figure 2 J

to the west of the areas where the hurricane deviated and looped, and lay nearly over the edge of the Continental Shelf (Figure 3J). Nevertheless, waters in which the temperature decreased by 1.5°C or more lay close to the path of the storm.

From an analysis of the actual inversion depths and temperature differences at each bathythermograph station, the heat loss during the 24-hour period chosen was calculated to be 21.5×10^{17} cal/day (an average of 6×10^{13} cal/sec). It is obvious that these values do not represent the total heat loss, for certainly energy was exchanged in waters of normal salinity lying southeast of Galveston. Even so, estimates of the probable heat transfer in these waters change the figure given by less than an order of magnitude.



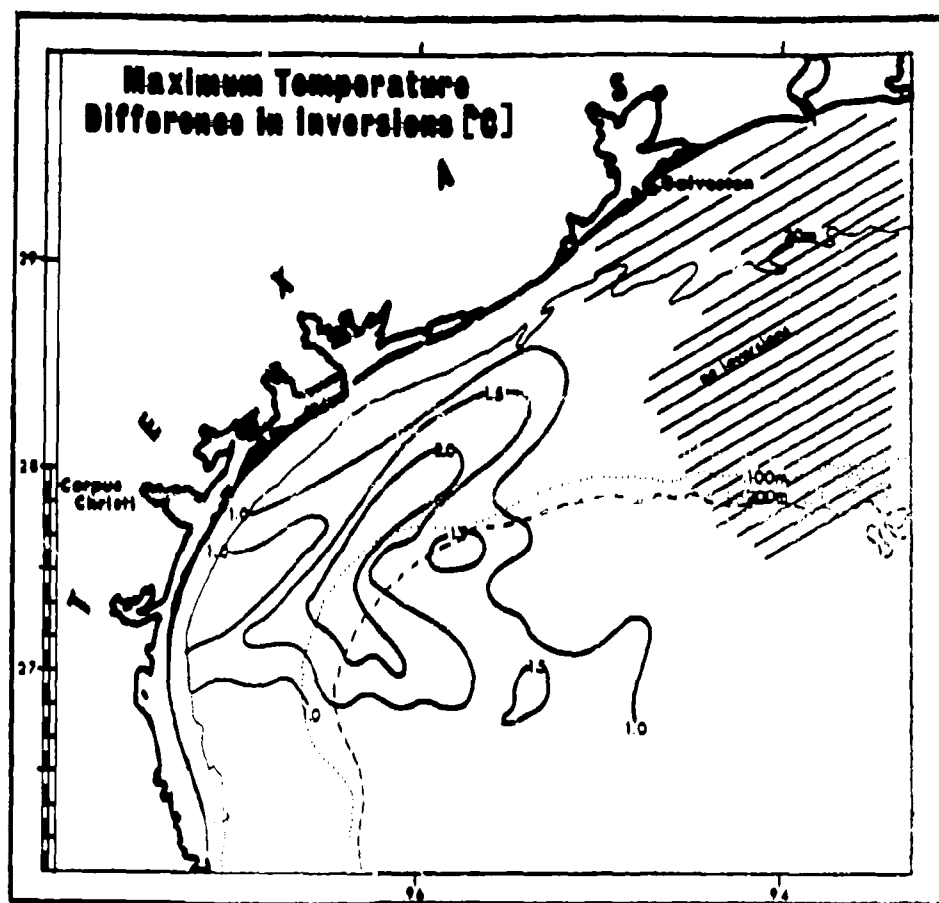


Figure 3 J

K. Instrumentation

George L. Huebner and Jack O. Hill

The following brief discussion concerns the effort on this project insofar as instrumentation development is concerned. Instrumentation, by its very nature, is of a support character and its usefulness is directly proportional to its contribution to the collection and analysis of data for oceanography and meteorology. By the above standards it is realized that much effort for various small problems is expended although it is not often written into a report.

The work for this year is roughly divided into the following major categories.

Telemetering Seismic System

During this fiscal year the design and construction of a telemetry system for remote sensing of seismic refraction data has been accomplished. The equipment is divided between the ship doing the shooting, in seismic profiling, and the moored buoy holding the receiving hydrophones.

The equipment mounted in the buoy is entirely self-contained and operates from storage batteries. A command signal from the "shooting ship" is received by the transistorized receiver in the buoy unit and starts a sequence of events. The received audio tone causes the control unit to select a specific gain setting for the hydrophone preamplifier. A zero or base line signal is then transmitted to allow the receiving ship to zero its receiving and recording galvanometers. Upon the completion of this interval, the transmitter is put into the normal transmitting mode. The seismic signal from the hydrophone is used to modulate an audio FM subcarrier, which, in turn modulates the single sideband transmitter. This is received by a standard Collins 32RS-1 transceiver on the "shooting ship." The transceiver's detector output is filtered and after audio discrimination, is used to drive the recording galvanometers. Upon the completion of a certain selected interval of time, the buoy equipment is returned to the receive condition to await the next command.

Field tests will begin soon after this report and will be presented in a technical report.

Design and Construction of Bathypitometers for Velocity Shear Measurement

The construction of a pair of bathypitometers for mounting on the research hoist at any position along the Contour Temperature Recorder chain has been accomplished this year.

Standard pitot tubes mounted on the hoist chain are fed to low pressure differential pressure transducers. The outputs of these transducers are an analogue of the speed of the pitot in line components. The analogue voltages are used to frequency modulate audio signals for transmission to the shipboard recording system. The vertical alignment of the pickup pitot systems is achieved through passage of the water. The ship heading determines the bearing alignment.

Velocity shear is obtained by algebraic addition of the analogue voltages.

Development of Technique for Calibration and Matching of Thermistors

The usual method of matching thermistors allows point matching as to the resistance temperature curve. Usually the thermistor is heated by passage of electrical current at the various points and often produces errors as much as 0.2°C or larger. A technique now under investigation is to determine the time constant of the thermistors under test and the platinum resistance secondary standard. By weighing either, the time constants are made equal. With the thermistor under test in physical contact with the platinum resistance thermometer, contact with a cold source is made until equilibrium is obtained. The heat content of the medium is changed in step function and the outputs of the voltage across the thermistor and the output of the Mueller Bridge are fed to the "x" and "y" axis inputs of an x-y recorder. It is thus easy to change parameters and determine the effect on the resistance-temperature curve.

Design and Construction of Electrical
and Electronic Systems for the
R/V ALAMINOS

During the latter portion of this fiscal year considerable effort was put into the design of the electrical power system for use on the new oceanographic ship R/V ALAMINOS. Much thought was given to the stability and low noise standby power for silent ship operation.

The major effort was directed toward the electronic data system. In addition to the standard radar, sonar, loran, and radio equipment, the most significant work was in connection with the data system. We have designed and are constructing a central digital data collection system that provides for 75 channels of data. The analogue voltages, resistances, and frequencies, are fed into the main data patch panel. There are 154 data lines terminating on the main panel. With these, the desired variables are patched into the sequential input scanners and the variables are programmed as to order, magnitude, type of signal; i.e., frequency, resistance, ac-dc volts, etc., the time of measurements, the interval between measurements and the integration time for each channel. Each channel in turn is sampled, normalized internally to set of units, printed on paper tape for visual storage, displayed on digital visual displays, and punched on paper tape for use in IBM computers.

Perhaps one of the significant items in the above is the normalization of the variables. With this feature, instead of arbitrary numbers, degrees C are displayed in degrees C, wind speed in knots, wind direction in degrees true, etc. The sampling rate is determined by the programmer and is controlled by a digital crystal controlled clock. Each sequence displays date, cruise number, time, position, heading, speed, etc., in addition to the other variables. The system is expandable to 100 channels if the need arises.

With the wide variety of input units as well as the extreme range of each, it is possible to take almost any variable from any of the laboratories and continuously record, at a fixed interval, the variations. The inputs are read to five significant places and are usually accurate to plus/minus one in the fifth place.

Each of the laboratories, the deck spaces, sonar well, and mast areas are connected to the central data panel. This allows

not only data collection from each of the areas but also allows the patching of signals from one area to the other without extra wiring.

It is felt that this gives an entirely new approach to oceanographic data collection and ease of analysis.

The following papers have been published during the contract year.

Antoine, J. and J. Ewing. "Seismic Refraction Measurements on the Margins of the Gulf of Mexico," J. Geophys. Res. 68(7), 1975-1996, April 1963.

Boyd, Donald W., Louis S. Kornicker, and R. Rezak. "Recent Algal Bioherms near Cozumel Island, Mexico," Abs. National Meeting, Geol. Soc. of Amer., Houston, Texas, November 1962.

Gual, R. D., J. M. Snodgrass, and D. J. Gretzler. "Some Dynamical Properties of the Savonius Rotor Current Meter," Marine Sciences Instrumentation, 2, ISA, Plenum Press, N.Y., 1963.

Hellier, Thomas R. Jr. and Louis S. Kornicker. "Sedimentation from a Hydraulic Dredge in a Bay," Inst. of Mar. Science, Univ. of Texas, v. 8, pp. 212-215, 1962.

Kornicker, Louis S. and Donald W. Boyd. "Shallow-water Geology and Environments of Alacran Reef Complex, Campeche Bank, Mexico," Am. Assoc. Petroleum Geologists Bull., v. 46, no. 5, pp. 640-673, May 1962.

Kornicker, Louis S. "Evolutionary Trends Among Mollusk Fecal Pellets," Jour. Paleontology, v. 36, no. 4, pp. 829-834, July 1962.

Kornicker, Louis S. and Donald F. Squires, "A Possible source of erroneous distribution data," Limn. and Ocn., v. 7, no. 4, pp. 447-452, October 1962.

Kornicker, Louis S. and Charles D. Wise. "Sarsiella (Ostracoda) in Texas Bays and Lagoons," Crustaceana, v. 4, pt. 1, pp. 57-74, 1962.

Kornicker, Louis S. "Ecology and classification of Bahamian Cytherellidae (Ostracoda)," Micropaleontology, v. 9, no. 1, pp. 61-70, January 1963.

Kornicker, Louis S. "The Bahama Banks: a 'living' Fossil-Environment," Jour. Geol. Edu., pp. 17-25, March 1963.

Kornicker, Louis S. "Hydrography and Sedimentology in the Vicinity of Bimini, Great Bahama Bank," Abs., Texas Jour. of Sci., v. 14, no. 4, p. 415, December 1962.

Rice, Winnie and Louis S. Kornicker. "Mollusks of Alacran Reef, Campeche Bank, Mexico," Inst. of Mar. Sci., Univ. of Texas, v. 8, pp. 366-403, 1962.

Stevenson, R. E. "The Climatic Amelioration in Southern California: 1955 to 1960," Jour. Applied Meteor., v. 1, no. 3, pp. 399-404.

Stevenson, R. E. "Sewage Disposal and the Sea in Southern California, Part 1 and Part 2," Water and Sewage Works. 1962.

Stevenson, R. E. "A Steam Fog at Galveston, Texas," Weatherwise, v. 15, no. 5.

Stevenson, R. E. and A. Collier. "Preliminary Observations on the Occurrence of Air-borne Marine Phytoplankton," Lloydia, v. 25, no. 2.

Wright, Thomas and Louis S. Kornicker. "Island Transport of Marine Shells by Birds on Perez Island Alacran Reef, Campeche Bank, Mexico," Jour. Geology, v. 70, no. 5, pp. 616-618, September 1962.

The following papers were presented at scientific meetings.

Antoine, J. and J. Ewing. "Seismic Refraction Measurements on the Margins of the Gulf of Mexico," Geol. Soc. Amer., Houston, Texas, November 1962.

Antoine, J. and J. Harding. "The Structure of Portions of the Northern Continental Shelf, Gulf of Mexico, as Determined by Seismic Refraction Measurements," Am. Assoc. of Petroleum Geologists, Houston, Texas, March 1963.

Cochrane, J. D. "The Upper Layers of Yucatan Current Adjacent to the Yucatan Shelf from April to November," Second Western National Meeting of the American Geophysical Union, Stanford Univ., Stanford, Calif., December 1962.

- Drennan, K. L., W. J. Demoran, and R. D. Gaul. "Some Results of Recent Circulation Studies East of the Mississippi Delta," 44th Annual Meeting of Amer. Geophys. Union, Washington, D. C., April 1963.
- Gaul, R. D., J. M. Snodgrass, and D. J. Cretzler. "Some Dynamical Properties of the Savonius Rotor Current Meter," Symposium on Transducers for Oceanic Research, San Diego, Calif., November 1962.
- Gaul, R. D., N. E. J. Boston, G. B. Dowling, and G. G. Salsman. "Dynamic Equilibrium of Thermal Structure in Shallow Water," Second Western National Meeting of Amer. Geophys. Union, Stanford Univ., Palo Alto, Calif., December 1962.
- Gaul, R. D. "Fixed Platforms for Oceanographic Research," Southwest IRE Conf., Dallas, Texas, April 1963.
- McLellan, H. J. and W. D. Nowlin. "Some Aspects of the Deep Water of the Gulf of Mexico," Second Ann. Meeting of Amer. Soc. of Limn. and Oceanog., Corvallis, Oregon, August 1962.
- McLellan, H. J. "Supplying Instruments for the Oceanographer to Use at Sea," Southwest IRE Conf., Dallas, Texas, April 1963.
- Stevenson, R. E. "Nearshore Winds and Currents of Guanabara State, Brazil," First International Conf. on Water Pollution Research, London, September 1962.
- Stevenson, R. E. "Temperature Changes in the Surface Waters of the Northwest Gulf of Mexico Resulting from Hurricane 'Carla'," Meteorologentagung, Seewetteramt, Hamburg, Germany, October 1962.
- Stevenson, R. E. "Winter Fogs Along the Texas Coast," Section Meeting, Am. Assoc. Geogs., San Antonio, Texas, April 1963.
- Tolbert, W. H., G. G. Salsman, and R. D. Gaul, "Results of Drift Bottle Studies off Panama City, Florida," 44th Annual Meeting of Amer. Geophys. Union, Washington, D. C., April 1963.

Vick, N. G. "A Report on Studies of the Morphometric Relationships and Systematic Status of Fishes of the Family Istiophoridae from the Gulf of Mexico," Texas Acad. of Sci., Austin, Texas, November 1962.

The following papers have been submitted for publication.

Cochrane, J. D. "Review of: Oceanographic Observations of the Pacific: 1955" The NORPAC ATLAS prepared by the NORPAC Committee. Limn. and Oceanog., 7(3). (In Press).

McLellan, H. J. and W. D. Nowlin. "Some Features of the Deep Water in the Gulf of Mexico," J. of Mar. Res. (In Press).

Stevenson, R. E. "Summer Fogs Along the Yorkshire Coast, England, in Commemorative Volume," K. O. Emery, Allan Hancock Fdn. (In Press).

Stevenson, R. E. "'Carla' Modifies Gulf Waters," Naval Res. Revs. (In Press).

Technical and data reports printed during the contract year through the Department of Oceanography and Meteorology.

Antoine, J. W. and J. L. Harding. "Structure of the Continental Shelf, Northeastern Gulf of Mexico," Ref. 63-13T, May 1963.

Dehlinger, P. and J. W. Antoine. "Seismic Refraction Profiles on the Outer Ridge North of Puerto Rico," September 1962.

Gaul, R. D. "Status of Environmental Research off Panama City, Florida," Ref. 63-2T, January 1963.

Jansen, J. F., Yasushi Kitano, Donald W. Hood, and Louis S. Kornicker. "The Resistance of Recent Marine Carbonate Sediments to Solution," Ref. 62-18T, 1962.

Kornicker, L. S. "Progress Report on Research Conducted in Geological Oceanography May 1, 1962 to April 30, 1963," Ref. 63-10A, 1962.

Kornicker, L. S. "Summary Report--Cruise 62-H-10, July 17-August 13, 1962, Galveston, Texas--Kingston, Jamaica--Nicaragua-Honduras Shelf," Ref. 62-15T, 1962.

Logan, B. W. "Classification and Environmental Significance of Stromatolites," Ref. 62-10T, 1962.

Logan, B. W. "Summary Report--Cruise 62-H-9, June 27-July 12, 1962, Galveston, Texas--Campeche Bank," Ref. 62-17T, 1962.

McLellan, H. J. and W. D. Nowlin. "The Waters of the Gulf of Mexico as Observed in February and March 1962," Ref. 62-16D, September 1962.

Williams, J. D. "The Petrology and Petrography of Sediments from the Sigsbee Blanket, Yucatan Shelf, Mexico," (Thesis), Ref. 63-12T, 1963.

Staff Travel

Antoine, John W.

January 1963. Washington, D. C. Dept. of the Navy, Bureau of Weapons Meeting.

Cochrane, John D.

June 1962. Washington, D. C. Intergovernmental Commission Working Group on the International Cooperative Investigations of the Tropical Atlantic as an Advisor for the United States.

July 1962. Scripps Institution of Oceanography, La Jolla, California.

March 1963. Oceanographic Institute of the University of Recife, Brazil.

April 1963. Oceanographic Institute of the University of Sao Paulo, Sao Paulo, Brazil.

April 1963. Research Vessel Almirante Saldanha, Rio de Janeiro, Brazil.

Gaul, Roy D.

May 1962. Attended National Telemetry Conference in Washington, D. C. Visited Public Health Service in Chicago concerning Great Lakes Survey Program.

September 1962. New Orleans, La. To install wave staff on offshore platform; and to Ocean Springs, Mississippi to plan cooperative field work with GCRL in October.

November 1962. San Diego, California. To attend and present paper at Instrument Society of America Symposium, and to conduct current meter testing at Hytech Div. of Bissett-Berman Corporation.

December 1962. To Bermuda (ARGUS ISLAND) to conduct joint field work with USN OCEANO; to New York for ISA publication conference; and to Washington for a conference on project business.

February 1963. To San Diego, California. To attend ONR Buoy Conference with Convair.

Hilli, Jack O.

November 1962. San Diego, California. Second ISA Science Instrumentation Symposium on Transducers for Oceanic Research.

March 1963. SMU, Dallas, Texas. Southwest Council of Divers Instruction Seminar.

Huebner, George L.

May 1962. Naval Research Laboratory, Washington, D. C. Workshop on Deep Ocean Techniques.

November 1962. San Diego, California. Naval Electronics Laboratory, U. S. Navy Underwater Symposium.

Kornicker, Louis S.

February 1963. Mexico City, Mexico. University of Mexico, for discussion concerning drilling on Arcas Reef, Campeche Bank, Mexico.

McLellan, Hugh J.

February 1963. San Diego, California. ONR Buoy Conference with Convair.

Stevenson, Robert E.

September 1962. England. National Institute of Oceanography.

September 1962. Paris, France. Centre de Recherches et d'Etudes oceanographiques.

September 1962. Antibes, France. Marine Statione, Centre de Recherches et d'Etudes oceanographiques.

September 1962. Netherlands. Geologisch Instituut, University of Groningen.

September 1962. De Bilt, Netherlands. Koninklijk Nederlands Meteorologisch Instituut.

October 1962. Wilhelmshaven, Germany. Forschungsanstalt, "Senckenberg am Meer."

October 1962. Hamburg, Germany. Geologisches Staatsinstitut, University of Hamburg.

October 1962. Germany. Institut für Meereskunde der Universität Kiel.

October 1962. Hamburg, Germany. Deutsches Hydrographisches Institut.

October 1962. Hamburg, Germany. Seewetteramt, Deutscher Wetterdienst.

November 1962. New York. Research Vessel Operators Council, New York University.

Personnel

The following personnel were employed in full or part-time capacity of this contract during the contract year.

+Leipper, D. F.	Project Supervisor
McLellan, Hugh J.	Chief Scientist
*Ahr, Wayne	Grad. Asst.
*Ahrens, John	Grad. Asst.
**Allison, Doris	Stenographer
*Alvarez, Jose A.	Grad. Asst.
Andrus, Charles W.	Tech. Asst. I
Andrus, Louis D.	Tech. Asst. II
Angino, E. E.	Assoc. Prof.
Antoine, John W.	Res. Sci. III
*Armstrong, Reed S.	Grad. Asst.
*Atwell, Buddy	Geophysicist
**Boston, Noel E. J.	Grad. Asst.
*Boudreau, Robert	Res. Sci. I
**Boatman, Geraldine	Clk. Typist I
*Bowman, Frank	Eng. Aid II
*Bullard, LaNelda F.	Stenographer
**Burkhalter, Morris G.	Draftsman
**Briggs, Kenneth	Grad. Asst.
Canglose, Jake	Res. Eng. II
**Canglose, Patrick P.	Tech.
Chancey, Oscar J.	Sr. Tech.
Cochran, Clifford A.	Tech. II
*Condit, R. J.	Stu. Asst.
**Cowling, Dorothy	Computer
**Chien, Chen-Wu	Res. Sci. II
**Dambolina, Ismael	Tech.
**Dehlinger, Peter	Geophysicists
**Eckelkamp, B. Jesse	Res. Eng. III
Eickenhorst, Otis	Res. Eng. I
Gaul, Roy D.	Res. Sci. III
Hill, Jack O.	Res. Sci. III
Hodges, Charles E.	Tech. II
*Holdredge, Margaret	Tech. Asst. I
*Hoover, Tom	Grad. Asst.
**Hubert, Frank W. R. Jr.	Tech. Asst.

**Ibert, E.	Res. Sci. III
*Jeffrey, Lela M.	Res. Sci. III
**Jansen, John	Grad. Asst.
**Jones, B. R.	Res. Geophysicist
Kelly, Daniel M.	Tech. II
*King, Charles	Res. Asst.
*Kirst, Alfred Jr.	Res. Eng. II
*Kornicker, Louis S.	Assoc. Prof.
*Koster, Samuel	Grad. Asst.
Lawhon, James M.	Tech. I
Letzring, Dean E.	Field Sci.
*Letzring, Marcia O.	Field Asst.
*Logan, Brian W.	Res. Sci. III
Looney, Milton P.	Tech. I
**Luther, Herbert A. M.	Eng. Aid
**Lyons, John A. Jr.	Tech. II
McMullen, R. G.	Res. Eng. II
McAdams, Anita L.	Computer
McQuilken, J. Ian	Res. Eng. III
**Mitra, Archana	Computer
Miller, Ron	Res. Sci. I
**Mooring, Elmer	Tech. Asst.
*Novasad, Ronnie	Stu. Asst.
Nowlin, W. D. Jr.	Res. Sci. I
O'Hara, Frank J.	Tech. III
Parker, Ruby D.	Computer I
**Parker, Jack	Grad. Asst.
*Pierce, Samuel C.	Tech. Asst. I
**Pitcher, Max	Grad. Asst.
**Polaski, Ila M.	Draftsman
*Pasby, Brian	Grad. Asst.
**Phalen, Winston C.	Captain - Research Vessel
*Raffield, W.C.	Tech. I
**Sell, Esther	Tech.
*Snead, Robert G.	Grad. Asst.
*Sommer, S.	Grad. Asst.
*Stevenson, Robert E.	Res. Sci.
*Smith, John	Stu. Asst.
Tharp, Earl	Tech. Asst.
Vick, Norman G.	Res. Sci. I
Vos, Everardus	Tech. I
**Walsh, Donald E.	Grad. Asst.
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**Williams, Joseph D.

*Winn, Henry L.

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**Wixson, Bobby

Wood, Arlene

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U. S. Weather Bureau
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